Εργαστήριο Επιχειρησιακών Ερευνών
Τμήματος Οικονομικών Επιστημών
Σχολής Ανθρωπιστικών και Κοινωνικών Επιστημών
Πανεπιστημίου Θεσσαλίας

1ο Πανελλήνιο Επιστημονικό Συνέδριο στην Οικονομική των Φυσικών Πόρων και του Περιβάλλοντος: Κλιματική Αλλαγή

ΠΡΑΚΤΙΚΑ ΣΥΝΕΔΡΙΟΥ

Βόλος, 26 – 27 Μαρτίου 2014

«ΣΥΝΕΡΓΑΣΙΑ 2011» 11SYN-8-118

ΕΥΡΩΠΑΪΚΗ ΕΝΩΣΗ
ΕΥΡΩΠΑΪΚΟ ΤΑΜΕΙΟ ΠΕΡΙΦΕΡΕΙΑΚΗΣ ΑΝΑΠΤΥΞΗΣ

Υπουργείο Παιδείας και Θρησκευμάτων
ΕΥΔΕ-ΕΤΑΚ

Ε. Π. Ανταγωνιστικότητα και Επιχειρηματικότητα (ΕΠΑΝ ΙΙ), ΠΕΠ Μακεδονίας – Θράκης, ΠΕΠ Κρήτης και Νήσων Αιγαίου, ΠΕΠ Θεσσαλίας – Στερεάς Ελλάδας – Ηπείρου, ΠΕΠ Αττικής

Το Εργαστήριο Επιχειρησιακών Ερευνών του Τμήματος Οικονομικών Επιστημών της Σχολής Ανθρωπιστικών και Κοινωνικών Επιστημών του Πανεπιστημίου Θεσσαλίας στα πλαίσια του ερευνητικού προγράμματος **ΣΥΝΕΡΓΑΣΙΑ 2011** και του έργου (**11SYN-8-118)** με τίτλο «*Σενάρια εκπομπών των αερίων του θερμοκηπίου και πολιτικές καταπολέμησής τους μέχρι το έτος 2030, στους τομείς της Ενέργειας, των Μεταφορών και της Βιομηχανίας στην Ελλάδα*» διοργάνωσε επιτυχώς το **1ο** Πανελλήνιο Συνέδριο Οικονομικής των Φυσικών Πόρων και του Περιβάλλοντος: Κλιματική Αλλαγή στις 26-27 Μαρτίου. Στα πλαίσια του ίδιου ερευνητικού προγράμματος θα διοργανωθεί το **2ο** Πανελλήνιο Συνέδριο στις 31 Οκτωβρίου - 1 Νοεμβρίου 2014 στις αίθουσες διδασκαλίας του Τμήματος (πρώην Γαλλικό Ινστιτούτο, Γ. Καρτάλη 72).

Το Συνέδριο αποσκοπεί στο να παρουσιάσει τα βασικά θέματα που απασχολούν σήμερα την Οικονομική των Φυσικών Πόρων και του Περιβάλλοντος με έμφαση στην Κλιματική Αλλαγή και στις πολιτικές επίλυσης του προβλήματος τόσο σε επίπεδο Ελλάδος όσο και σε παγκόσμιο επίπεδο. Σκοπός του είναι η ανταλλαγή απόψεων και εμπειριών άμεσα συνδεδεμένων με το φαινόμενο του θερμοκηπίου.

Επιστημονικός Υπεύθυνος Συνεδρίου

Καθηγητής Γεώργιος Ε. Χάλκος
Διευθυντής Εργαστηρίου Επιχειρησιακών Ερευνών
Τμήματος Οικονομικών Επιστημών
Σχολής Ανθρωπιστικών και Κοινωνικών Επιστημών
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ENVECON 2014

Περιεχόμενα

Ιστοσελίδα συνεδρίου και επισκέψεις

http://envecon2014.econ.uth.gr/main/

ΕΠΙΤΡΟΠΕΣ ΣΥΝΕΔΡΙΟΥ

ΕΠΙΣΤΗΜΟΝΙΚΗ ΕΠΙΤΡΟΠΗ ΣΥΝΕΔΡΙΟΥ

- Γιαννακόπουλος Αθανάσιος, Καθηγητής, Οικονομικό Πανεπιστήμιο Αθηνών
- Διακουλάκη Δανάη, Καθηγήτρια ΕΜΠ
- Δονάτος Γεώργιος, Καθηγητής, Πανεπιστήμιο Αθηνών
- Κοκκώσης Χάρης, Καθηγητής, Πανεπιστήμιο Θεσσαλίας
- Κούγκολος Αθανάσιος, Καθηγητής, Πανεπιστήμιο Θεσσαλίας
- Μάττας Κων/νος, Καθηγητής, Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης
- Μαυράκης Δημήτριος, Καθηγητής, ΚΕΠΑ Πανεπιστήμιο Αθηνών
- Ξεπαπαδέας Αναστάσιος, Καθηγητής, Οικονομικό Πανεπιστήμιο Αθηνών
- Σαρτζετάκης Ευτύχης, Καθηγητής, Πανεπιστήμιο Μακεδονίας
- Σκούρτος Μιχάλης, Καθηγητής, Πανεπιστήμιο Αιγαίου
- Τσιώνας Ευθύμιος, Καθηγητής, Οικονομικό Πανεπιστήμιο Αθηνών
- Χονδρογιάννης Γεώργιος, Καθηγητής, Χαροκόπειο Πανεπιστήμιο
- Χριστόπουλος Δημήτριος, Καθηγητής, Πάντειο Πανεπιστήμιο
- Βαφείδης Δημήτριος, Αναπ. Καθηγητής, Πανεπιστήμιο Θεσσαλίας
- Κοντογιάννη Αρετή, Αναπ. Καθηγήτρια, Πανεπιστήμιο Δυτικής Μακεδονίας
- Κουντούρη Φοίβη, Αναπ. Καθηγήτρια, Οικονομικό Πανεπιστήμιο Αθηνών
- Μπίθας Κων/νος, Αναπ. Καθηγητής, Πάντειο Πανεπιστήμιο
- Καμπάς Αθανάσιος, Επικ. Καθηγητής, Γεωπονικό Πανεπιστήμιο Αθηνών
- Κεβόρκ Ηλίας, Επικ. Καθηγητής, Πανεπιστήμιο Θεσσαλίας
- Ματσιώρη Στεριανή, Επικ. Καθηγήτρια, Πανεπιστήμιο Θεσσαλίας
- Τζερεμές Νικόλαος, Επικ. Καθηγητής, Πανεπιστήμιο Θεσσαλίας

Συντονιστές Ακαδημαϊκών Περιοδικών Συνεδρίου

- Κίτσος Χρήστος, Καθηγητής, ΑΤΕΙ Αθηνών
- Κορρές Γεώργιος, Καθηγητής, Πανεπιστήμιο Αιγαίου
- Ευαγγελινός Κων/νος, Επικ. Καθηγητής, Πανεπιστήμιο Αιγαίου
- Νικολάου Ιωάννης, Επικ. Καθηγητής, Δημοκρίτειο Πανεπιστήμιο Θράκης

3. ΟΡΓΑΝΩΤΙΚΗ ΕΠΙΤΡΟΠΗ ΣΥΝΕΔΡΙΟΥ

- Παπαγεωργίου Γεώργιος, Πανεπιστήμιο Θεσσαλίας
- Τσιλίκα Κορίνα, Πανεπιστήμιο Θεσσαλίας
- Γαλάνη Γεωργία, Πανεπιστήμιο Θεσσαλίας
- Τζερεμές Παναγιώτης, Πανεπιστήμιο Θεσσαλίας
- Κουρτζίδης Σταύρος, Πανεπιστήμιο Θεσσαλίας
- Τζιουρτζιούμης Χρήστος, Πανεπιστήμιο Θεσσαλίας
- Τζιβινίκος Τρύφωνας, Πανεπιστήμιο Θεσσαλίας
- Παιζάνος Επαμεινώνδας, Πανεπιστήμιο Θεσσαλίας
- Κίτσου Δήμητρα, Πανεπιστήμιο Θεσσαλίας
- Γεωργούδης Γεώργιος, Πανεπιστήμιο Θεσσαλίας
- Βαρζάκα Χρυσαφούλα, Πανεπιστήμιο Θεσσαλίας

4. ΤΕΧΝΙΚΗ ΥΠΟΣΤΗΡΙΞΗ

- Γεώργιος Θάνος, Πανεπιστήμιο Θεσσαλίας

Συνοπτικό Πρόγραμμα Συνεδρίου

Ημέρα	Ώρα	Συνεδρίες - Θεματολογία
Τετάρτη 26/3/2014	10:30-11:00	Εγγραφή σύνεδρων
	11:00-11:30 Αμφιθέατρο	Καλωσόρισμα Σύνεδρων
	11:30-13:30 Αμφιθέατρο	**ΣΥΝΕΔΡΙΑ 1:** Εκτίμηση Περιβαλλοντικών Επιπτώσεων
	11:30-13:15 Αίθουσα 4	**ΣΥΝΕΔΡΙΑ 2:** Επιχειρήσεις και Περιβάλλον: Εταιρική Κοινωνική Ευθύνη
	13:30-14:30 Αίθουσα 3	Διάλειμμα (Γεύμα)
	14:30-16:35 Αμφιθέατρο	**ΣΥΝΕΔΡΙΑ 3:** Ποσοτικές Μέθοδοι Οικονομικής Φυσικών Πόρων και Περιβάλλοντος **Ι**
	16:35-17:05 Αίθουσα 3	Διάλειμμα (καφές, αναψυκτικά)
	17:05-19:10 Αμφιθέατρο	**ΣΥΝΕΔΡΙΑ 4:** Αστική και Περιφερειακή Ανάπτυξη – Περιβάλλον
	17:05-19:10 Αίθουσα 4	**ΣΥΝΕΔΡΙΑ 5:** Πράσινη Οικονομία, Βιωσιμότητα, Καινοτομία
	19:15-20:30 Αίθουσα 3	Δείπνο
Πέμπτη 27/3/2014	9:00-10:40 Αμφιθέατρο	**ΣΥΝΕΔΡΙΑ 6:** Οικονομική Ανάπτυξη και Περιβάλλον: Κλιματική αλλαγή
	10:40-11:10 Αίθουσα 3	Διάλειμμα (καφές, αναψυκτικά)
	11:10-13:15 Αμφιθέατρο	**ΣΥΝΕΔΡΙΑ 7:** Οικονομική Αξιολόγηση Περιβάλλοντος
	13:15-14:30 Αίθουσα 3	Διάλειμμα (Γεύμα)
	14:30-16:30 Αμφιθέατρο	**ΣΥΝΕΔΡΙΑ 8:** Ποσοτικές Μέθοδοι Οικονομικής Φυσικών Πόρων και Περιβάλλοντος **ΙΙ**
	14:30-16:15 Αίθουσα 4	**ΣΥΝΕΔΡΙΑ 9:** Βιώσιμος Τουρισμός – Βιοποικιλότητα
	16:15-16:45 Αίθουσα 3	Διάλειμμα (καφές, αναψυκτικά)
	16:45-18:45 Αμφιθέατρο	**ΣΥΝΕΔΡΙΑ 10:** Περιβαλλοντικά Προβλήματα: Αποτελέσματα Ερευνητικών Προγραμμάτων
	16:45-18:25 Αίθουσα 4	**ΣΥΝΕΔΡΙΑ 11:** Βιώσιμες Μεταφορές
	18:30 Αμφιθέατρο	Δεξίωση Λήξης Συνεδρίου

ΠΡΟΓΡΑΜΜΑ ΣΥΝΕΔΡΙΟΥ

Τετάρτη 26 Μαρτίου 2014

1η Συνεδρία: 11:30-13:30 Αμφιθέατρο

Θεματική:	Εκτίμηση Περιβαλλοντικών Επιπτώσεων
Προεδρία:	Χ. Κίτσος

11:30-11:50	Investors' Reactions to Natural and Anthropogenic Adversity Kollias C. and Papadamou S. Department of Economics, University of Thessaly
11:50-12:10	Nuclear events with their Socio - Environmental effects Kitsos C. Department of Informatics Technological Educational Institute of Athens, Greece
12:10-12:30	Αξιολόγηση μελέτης περιβαλλοντικών επιπτώσεων με χρήση αλγορίθμου ποιότητας Καζαμίας Π., Παπακωνσταντίνου Δ., Κασσιός Κ. Εθνικό Μετσόβιο Πολυτεχνείο, Σχολή Αγρονόμων Τοπογράφων Μηχανικών
12:30-12:50	Αξιοποίηση των αρχών της Βιομηχανικής Οικολογίας για την αποτίμηση της περιβαλλοντικής βιωσιμότητας επιχειρήσεων Αγγελάκογλου Κ. και Γκαϊντατζής Γ. Τμήμα Μηχανικών Παραγωγής και Διοίκησης, Πολυτεχνική Σχολή, Δημοκρίτειο Πανεπιστήμιο Θράκης
12:50-13:10	Προς μία στρατηγική προσαρμογής στην Κλιματική Αλλαγή: Ο ρόλος της εκτίμησης περιβαλλοντικών επιπτώσεων Σκριμιζέα Ε., Παπακωνσταντίνου Δ. Παπαδοπούλου Μ. Εθνικό Μετσόβιο Πολυτεχνείο, Σχολή Αγρονόμων Τοπογράφων Μηχανικών
13:10-13:30	Συζήτηση

2η Συνεδρία: 11:30-13:15 Αίθουσα 4

Θεματική:	Επιχειρήσεις και Περιβάλλον: Εταιρική Κοινωνική Ευθύνη
Προεδρία:	Α. Γιαννακόπουλος

11:30-11:50	Εταιρική Κοινωνική Ευθύνη: Οι αντιλήψεις των καταναλωτών για τις περιβαλλοντικές πρακτικές των επιχειρήσεων Σταυροπούλου, Α., Κωστάκης, Ι., Σαρδιανού, Ε. Χαροκόπειο Πανεπιστήμιο
11:50-12:10	Social responsibility and environmental management policies in higher education Sepetis A.[1] and Rizos F.[2] [1] General Hospitals of Lamia, Technological Institute of Athens [2] University of Piraeus
12:10-12:30	Environmental policy and CSR: How climate change is interpreted in CSR reports of Greek companies Metaxas T[1] and Tsavdaridou M.[2] [1] University of Thessaly Department of Economics [2] University of Thessaly Department of Planning and Regional Development
12:30-12:50	From Green Policy to Results in Greece- The Response of Greek Firms to the National Call for Boosting Green Entrepreneurship Markatou M. University of Thessaly, Unit for Innovation and Entrepreneurship
12:50-13:15	Συζήτηση

3η Συνεδρία: 14:30-16:35 Αμφιθέατρο

Θεματική:	Ποσοτικές Μέθοδοι Οικονομικής Φυσικών Πόρων και Περιβάλλοντος **I**
Προεδρία:	Κ. Μάττας

14:30 – 14:50	Learning the Dynamics of Climate Change: An Experimental Analysis Nastis S. and Mattas K. Aristotle University of Thessaloniki School of Agriculture Department of Agricultural Economics
14:50-15:10	On the dynamic linkages between CO_2 emissions, energy consumption and growth in Greece Katrakilidis C., Kyritsis I., and Patsika V. Aristotle University of Thessaloniki
15:10-15:30	Confidence intervals for percentiles in stationary ARMA processes: An application using environmental data Halkos G. and Kevork I. Laboratory of Operations Research, Department of Economics University of Thessaly
15:30-15:50	Exploring climate change issues related to water resources and agriculture in Cyprus, employing a Delphi type method Markou M.[1], Michailidis A.[2], Loizou E.[3] and Mattas K.[2] [1] Agricultural Research Institute, Nicosia, Cyprus [2] Aristotle University of Thessaloniki, Thessaloniki, Greece, [3] Technological Educational Institution of Western Macedonia
15:50-16:10	Climate Change Policy under Spatially Structured Ambiguity: Hot Spots and the Precautionary Principle Xepapadeas A. and Yannacopoulos A. Department of International and European Economic Studies and Department of Statistics, Athens University of Economics and Business
16:10-16:35	Συζήτηση

$4^{η}$ Συνεδρία: 17:05-19:10 Αμφιθέατρο

Θεματική:	Αστική και Περιφερειακή Ανάπτυξη – Περιβάλλον
Προεδρία:	Ν. Τζερεμές

17:05-17:25 Population, economic growth and regional environmental performance: A conditional range directional distance function approach
Halkos G. and Tzeremes N.
Laboratory of Operations Research, Department of Economics, University of Thessaly

17:25-17:45 Η Αστικοποίηση στην Ανατολική Μεσόγειο και οι επιδράσεις της στην ατμοσφαιρική ρύπανση, το κλίμα και το οικοσύστημα: Η περίπτωση του Λεκανοπεδίου Αττικής
Σοφίου Φ.Ι., Παπακωνσταντίνου Δ., Κασσιός Κ.
Εθνικό Μετσόβιο Πολυτεχνείο, Σχολή Αγρονόμων Τοπογράφων Μηχανικών,

17:45-18:05 Ευρωπαϊκή και Ελληνική Πολιτική Βιώσιμης Αστικής Κινητικότητας και Δείκτες Αστικής Αειφορίας
Γαλάνης Α. και Ηλιού Ν.
Πανεπιστήμιο Θεσσαλίας, Τμήμα Πολιτικών Μηχανικών

18:05-18:25 Τραγωδία ή ευκαιρία; Ζητήματα διαχείρισης των υπόγειων υδάτων στη Θεσσαλία.
Αρβανιτίδης Π. και Νασιώκα Φ.
Τμήμα Οικονομικών Επιστημών, Πανεπιστήμιο Θεσσαλίας

18:25-18:45 A multilevel analysis of the determinants of individual well-being in European countries
Economou A. and Raptis A.
Department of Economics, University of Thessaly

18:45-19:10 Συζήτηση

5η Συνεδρία: 17:05-19:10 Αίθουσα 4

Θεματική:	Πράσινη Οικονομία, Βιωσιμότητα, Καινοτομία
Προεδρία:	Κ. Ευαγγελινός - Ι. Νικολάου

17:05-17:25

Exploring ***organizational accountability*** in relation to ***climate change: Where do Greek corporations stand?***

Skouloudis A.[1], Malesios Ch.[2] and Evangelinos K.[1]
[1] Centre for Environmental Policy and Strategic Environmental Management, Department of Environment, University of the Aegean
[2] Department of Agricultural Development, Democritus University of Thrace

17:25-17:45

The Sustainable (Eco) Innovation Output in the OECD Area: a Patent Analysis

Markatou M.[1] and Stamboulis Y.[2]
[1] University of Thessaly, Unit for Innovation and Entrepreneurship
[2] University of Thessaly, Department of Economics- Unit for Innovation and Entrepreneurship

17:45-18:05

Regional sustainability efficiency indexes in Europe: An additive two-stage DEA approach

Halkos G., Tzeremes N., Kourtzidis S.
Laboratory of Operations Research, Department of Economics, University of Thessaly

18:05-18:25

Environmental policies and eco-innovation

Georgatzi V[1] and Stamboulis Y[2]
[1] Economist, MSc
[2] Department of Economics, University of Thessaly

18:25-18:45

Sustainable Future Eco Landmarks: Πρότυπη εφαρμογή Αειφόρας Ανάπτυξης με επίκεντρο πολιτιστικό τοπόσημο περιοχής

Ανδρεόπουλος Α.
M.Ed., σύμβουλος Αειφόρας Ανάπτυξης, Sustainable Future Eco Landmarks instigator; METIS Accredited Observer to UNFCCC; UNESCO Task Force.

18:45-19:10

Συζήτηση

Πέμπτη 27 Μαρτίου 2014

6η Συνεδρία: 9:00-10:40 Αμφιθέατρο

Θεματική:	Οικονομική Ανάπτυξη και Περιβάλλον: Κλιματική Αλλαγή
Προεδρία:	Δ. Διακουλάκη

09:00-09:20	Οικονομική ανάπτυξη και Περιβάλλον: Ισχύει η υπόθεση της περιβαλλοντικής καμπύλης Kuznets; Χάλκος Γ. Laboratory of Operations Research, Department of Economics, University of Thessaly
09:20-09:40	Exploring the Energy-Growth link by investigating E-GDP causal relationship and decoupling estimations: the cases of USA and China Kalimeris P., Bithas K., Richardson C. Institute of Urban Environment & Human Resources, Department of Economic and Regional Development, Panteion University,
09:40-10:00	Ερμηνευτικοί παράγοντες της μεταβολής των εκπομπών CO_2 στην Ευρωπαϊκή Ένωση πριν και μετά την οικονομική κρίση Διακουλάκη Δ., Κοπίδου Δ. Εθνικό Μετσόβιο Πολυτεχνείο, Σχολή Χημικών Μηχανικών Εργαστήριο. Βιομηχανικής & Ενεργειακής Οικονομίας
10:00- 10:20	Environmental Management Systems in SMEs – The Impact of Economic Crisis Nikolaou I.[1], Daktyla M.[1] and Evangelinos K.[2] [1] Department of Environmental Engineering, Democritus University of Thrace. [2] Department of Environmental Studies, University of the Aegean.
10:20-10:40	Συζήτηση

7η Συνεδρία: 11:10-13:15 Αμφιθέατρο

Θεματική:	Οικονομική Αξιολόγηση Περιβάλλοντος
Προεδρία:	Μ. Σκούρτος

11:10-11:30	The impact of social capital on willingness-to-pay for hard engineered coastal defenses in south-east England Jones N.[1], Clark J.R.A.[2], Malesios Ch.[3], Evangelinos K.[4] [1] Open University [2] University of Birmingham [3] Democritus University of Thrace [4] University of the Aegean
11:30-11:50	Implementing the European Water Framework Directive in Greece: An Integrated Socio-Economic Approach and Remaining Obstacles Koundouri P[1] and Dávila O.G.[2] [1] Athens University of Economics and Business [2] University of London
11:50-12:10	A Real Option framework towards analyzing coastal protection to sea level rise Damigos D.[1], Kontogianni A.[2], Tourkolias Ch.[3], Skourtos M.[3], Andreadis O.[4], Velegrakis A.[4] [1] National Technical University of Athens [2] University of Western Macedonia [3] Agricultural University of Athens [4] University of Aegean, Department of Marine Science
12:10-12:30	The value of scientific information on climate change: a choice experiment on Rokua esker, Finland Koundouri P.[1], Kougea E.[1], Stithou M.[1], Alaaho P.[2], Eskelinen R.[2], Karjalainen T,P.[2], Klove B.[2], Pulido-Velazquez M.[3], Reinikainen K.[4] and Rossi P.M.[2] [1]Athens University of Economics and Business [2] University of Oulu, Finland; [3] Universitat Polite`cnica de Valencia, Spain; [4] Poyry Finland
12:30-12:50	On the Use of Quadratic Trends in Natural Resource Prices Modelling Antypas A.[1], Koundouri P.[2], Kourogenis N.[1] [1] University of Piraeus [2] Athens University of Economics and Business
12:50-13:15	Συζήτηση

8η Συνεδρία: 14:30-16:30 Αμφιθέατρο

Θεματική:	Ποσοτικές Μέθοδοι Οικονομικής Φυσικών Πόρων και Περιβάλλοντος **II**
Προεδρία:	Γ. Χάλκος

14:30-14:50	Managing environmental services as a renewable resource Halkos G. and Papageorgiou G. Laboratory of Operations Research, Department of Economics, University of Thessaly
14:50-15:10	Regulating climate change using geoengineering methods when countries are heterogeneous Manousi V. and Xepapadeas A. Athens University of Economics and Business, Department of International and European Economic Studies
15:10-15:30	Managing Local Commons: Fairness vs Stability for the Management of Mediterranean Tuna Koutsouba K. and Kampas A. Department of Agricultural Economics and Rural Development, Agricultural University of Athens,
15:30-15:50	Using a general equilibrium model to evaluate first mover advantage in climate policy Karkatsoulis P., Paroussos L., Fragkos P. and Capros P. E3MLab at National Technical University of Athens
15:50-16:10	A regional model for analysis and visualization of the synergistic impact mechanism of climate related costs Halkos G. and Tsilika K. Laboratory of Operations Research, Department of Economics, University of Thessaly
16:10-16:30	Συζήτηση

9η Συνεδρία: 14:30-16:15 Αίθουσα 4

Θεματική:	Βιώσιμος Τουρισμός - Βιοποικιλότητα
Προεδρία:	Σ. Ματσιώρη

14:30-14:50	Integrating visitors' motivations for planning tourism events: An empirical research Ekonomou G., Neofitou C. and Matsiori S. Department of Ichthyology and Aquatic Environment, University of Thessaly
14:50-15:10	Κλιματική αλλαγή και οι επιπτώσεις της σε παράκτιους προορισμούς μαζικού τουρισμού στη Μεσόγειο Δάλλας Ν., Κωστοπούλου Σ. Τομέας Ανάπτυξης και Προγραμματισμού, Τμήμα Οικονομικών Επιστημών, Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης
15:10-15:30	Η φυσιολογία διατήρησης ως «εργαλείο» εκτίμησης κινδύνου των θαλάσσιων οργανισμών λόγω επίδρασης της κλιματικής αλλαγής Μιχαηλίδης Β. Εργαστήριο Φυσιολογίας Ζώων, Τμήμα Βιολογίας, Σχολή Θετικών Επιστημών, Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης
15:30-15:50	Προσδιορισμός παραγόντων απόδοσης οικονομικής αξίας στη θαλάσσια βιοποικιλότητα Matsiori S., Varsamoudi P., Exadactylos A., Vafidis D. Department of Ichthyology and Aquatic Environment, School of Agricultural Sciences University of Thessaly
15:50-16:15	Συζήτηση

10η Συνεδρία: 16:45-18:45 Αμφιθέατρο

Θεματική:	Περιβαλλοντικά Προβλήματα: Αποτελέσματα Ερευνητικών Προγραμμάτων
Προεδρία:	Γ. Χάλκος
16:45-17:05	An analysis of long-term scenarios for the transition to renewable energy in Greece <u>Halkos G., Galani G. and Tzeremes P.</u> Laboratory of Operations Research, Department of Economics, University of Thessaly
17:05-17:25	Development and evaluation of Mitigation/Adaptation policy portfolios in countries with emerging economies PROMITHEAS – 4 project results <u>Mavraki E-D and Flessa A.</u> Energy Policy and Development Centre (KEPA), National and Kapodistrian University of Athesn
17:25-17:45	Ανάλυση συγκεντρώσεων αιωρούμενων σωματιδίων PM_{10} ΚΑΙ $PM_{2.5}$ στην περιοχή του Βόλου κατά τη θερινή και χειμερινή περίοδο 2011–2012 στο πλαίσιο του προγράμματος LIFE + ACEPT-AIR <u>Πρώιας Γ.[1], Κούγκολος Α.[1], Πολύζος Σ.[1] και Ελευθεριάδης Κ.[2]</u> [1] Πανεπιστήμιο Θεσσαλίας, Πολυτεχνική Σχολή, Τμήμα Μηχανικών Χωροταξίας Πολεοδομίας, Χωροταξίας και Περιφερειακής Ανάπτυξης [2] ΕΚΕΦΕ Δημόκριτος, Εργαστήριο Περιβάλλοντος και Ραδιενέργιας, Ινστιτούτο Πυρηνικής Τεχνολογίας και Ακτινοβολίας [3]Γενικό Τμήμα Μαθηματικών, ΤΕΙ Πειραιά
17:45-18:05	Generalizing Pollution Social Cost <u>Halkos G. and Kitsou D.</u> Laboratory of Operations Research, Department of Economics University of Thessaly
18:05-18:25	The effect of economic growth and government expenditure on the environment: evidence using distributed lag models <u>Halkos G. and Paizanos E.</u> Laboratory of Operations Research, Department of Economics, University of Thessaly
18:25-18:45	Συζήτηση

11η Συνεδρία: 16:45-18:25 Αίθουσα 4

Θεματική:	Βιώσιμες Μεταφορές
Προεδρία:	Η. Κεβόρκ

16:45-17:05 Climate change, environmental effects of transport modes and transportation planning
Profillidis V.and Botzoris G.
Democritus University of Thrace, Department of Civil Engineering

17:05-17:25 Sustainable Transportation and Development: A preventing weapon against Climate Change
Stergiadou A.
Aristotle University of Thessaloniki Faculty of Agriculture, Forestry & Natural Environment

17:25-17:45 Sustainable Transportation Planning and Traffic Noise reduction in Urban Built Environment
Galanis A.[1], Botzoris G.[2] and Eliou N.[1]
[1] University of Thessaly, Department of Civil Engineering
[2] Democritus University of Thrace, Department of Civil Engineering

17:45-18:05 Οικονομικοτεχνικοί παράγοντες που επηρεάζουν τα έργα διάνοιξης του δάσους στην ορεινή περιοχή του Μετσόβου με σκοπό τη βιώσιμη ανάπτυξη της
Ταμπέκης Σ.
Τμήμα Μηχανικών Χωροταξίας Πολεοδομίας και Περιφερειακής Ανάπτυξης, Πολυτεχνική Σχολή, Πανεπιστήμιο Θεσσαλίας

18:05-18:25 Συζήτηση

ΠΡΑΚΤΙΚΑ ΣΥΝΕΔΡΙΟΥ

ΣΥΝΟΨΗ ΠΡΑΚΤΙΚΩΝ

Το πρόγραμμα του συνεδρίου αποτελούνταν από 11 συνεδρίες που έλαβαν χώρα στις αίθουσες διδασκαλίας του Τμήματος Οικονομικών Επιστημών του Πανεπιστημίου Θεσσαλίας. Οι 11 θεματικές ενότητες που παρουσιάστηκαν αφορούσαν την Εκτίμηση Περιβαλλοντικών Επιπτώσεων, τις Επιχειρήσεις και το Περιβάλλον: Εταιρική Κοινωνική Ευθύνη, τις Ποσοτικές Μεθόδους Οικονομικής των Φυσικών Πόρων και του Περιβάλλοντος, την Αστική και Περιφερειακή Ανάπτυξη σε σχέση με το Περιβάλλον, την Πράσινη Οικονομία, τη Βιωσιμότητα και την Καινοτομία, την Οικονομική Μεγέθυνση και το Περιβάλλον, την Οικονομική Αξιολόγηση του Περιβάλλοντος, τη Θεωρία Παιγνίων, το Βιώσιμο Τουρισμό, τη Βιοποικιλότητα καθώς και τα αποτελέσματα κάποιων Περιβαλλοντικών Ερευνητικών Προγραμμάτων μεταξύ των οποίων και αυτά του ερευνητικού προγράμματος ΣΥΝΕΡΓΑΣΙΑ 2011 και του έργου 11SYN-8-118.

Στα πρακτικά του συνεδρίου συμπεριελήφθηκαν 45 μελέτες. Οι πρώτες πέντε εργασίες των πρακτικών του συνεδρίου παρουσιάζουν τα αποτελέσματα διαφόρων ερευνητικών προγραμμάτων σχετικών με την αντιμετώπιση των περιβαλλοντικών προβλημάτων. Η 1η εργασία των Χάλκου, Γαλάνη Γ. και Τζερεμέ Π. παρουσιάζει μία εκτενή ανάλυση των μακροχρόνιων σεναρίων μετάβασης σε χρήση ανανεώσιμων πηγών ενέργειας στην Ελλάδα από τα αποτελέσματα του ερευνητικού προγράμματος ΣΥΝΕΡΓΑΣΙΑ 2011 και του έργου 11SYN-8-118 με τίτλο «Σενάρια εκπομπών των αερίων του θερμοκηπίου και πολιτικές καταπολέμησής τους μέχρι το έτος 2030, στους τομείς της Ενέργειας, των Μεταφορών και της Βιομηχανίας στην Ελλάδα». Η 2η εργασία των Μαυράκη Ε.Δ. και Φλέσσα Α. παρουσιάζει τα αποτελέσματα του ερευνητικού προγράμματος PROMITHEAS-4 δίνοντας βαρύτητα στην ανάπτυξη και εκτίμηση των πολιτικών ελέγχου και προσαρμογής και αναδεικνύοντας τις ανάγκες σε γνώσεις, τόσο στο επίπεδο των πολιτικών, όσο και στο επίπεδο της υποστήριξης τους. Η 3η μελέτη των Πρώια, Κούγκολου, Πολύζου και Ελευθεριάδη παρουσιάζει τα αποτελέσματα των μετρήσεων που έγιναν στα πλαίσια του προγράμματος Περιβαλλοντικής Πολιτικής Life+ ACEPT-AIR από το Σεπτέμβριο του 2009. Συγκεκριμένα αναλύονται οι συγκεντρώσεις αιωρούμενων σωματιδίων PM_{10} ΚΑΙ $PM_{2.5}$ στην περιοχή του Βόλου κατά τη θερινή και χειμερινή περίοδο 2011–2012 και με προσπάθεια σύγκρισης με αντίστοιχα αποτελέσματα άλλων μελετών της διεθνούς βιβλιογραφίας για άλλες περιοχές. Οι τελευταίες δύο εργασίες έγιναν στα πλαίσια του ΗΡΑΚΛΕΙΤΟΣ. Συγκεκριμένα, η 4η εργασία των Χάλκου και Κίτσου Δ. παρέχει μια γενίκευση του αναμενόμενου κοινωνικού κόστους της ρύπανσης επικεντρώνοντας στη γενική του μορφή αλλά και στη χρήση διαφόρων συναρτήσεων πυκνότητας πιθανότητας. Ομοίως η 5η εργασία των Χάλκου και Παιζάνου βασιζόμενη σε υποδείγματα κατανεμημένων χρονικών υστερήσεων εξετάζει την επίδραση της οικονομικής μεγέθυνσης και των κυβερνητικών δαπανών στο περιβάλλον.

Οι επόμενες τέσσερεις μελέτες ασχολούνται με την οικονομική ανάπτυξη και το περιβάλλον με έμφαση στην κλιματική αλλαγή. Η $6^{η}$ μελέτη του Γ. Χάλκου απαντά στο ερώτημα αν ισχύει η υπόθεση της περιβαλλοντικής καμπύλης Kuznets εξηγώντας την έννοια της υπόθεσης αυτής. Με τη χρήση κατάλληλων οικονομετρικών μεθόδων ανάλυσης panel δεδομένων εξετάζεται εμπειρικά η σχέση εκπομπών CO_2/c και ΑΕΠ/c δείχνοντας ότι η ύπαρξη ετερογένειας μεταξύ των χωρών απαιτεί προσεκτική υποδειγματοποίηση και υιοθέτηση κατάλληλων πολιτικών αντιμετώπισης των περιβαλλοντικών προβλημάτων. Η $7^{η}$ εργασία των Καλημέρη, Μπίθα και Richardson εξερευνεί εμπειρικά την αιτιώδη σχέση ενέργειας-οικονομικής μεγέθυνσης στις περιπτώσεις των ΗΠΑ και της Κίνας. Για το σκοπό αυτό γίνεται μία ιστορική αναδρομή για τις δύο αυτές χώρες σε σχέση με την εμπειρική υποστήριξη της διερεύνησης ύπαρξης αιτιώδους σχέσης μεταξύ ενεργειακής χρήσης και ΑΕΠ σε συνεργασία με την εκτίμηση του αποτελέσματος αποσύνδεσης της ενεργειακή έντασης ανά μονάδα ΑΕΠ και των εκπομπών CO_2 ανά μονάδα ΑΕΠ. Η $8^{η}$ μελέτη των Διακουλάκη και Κοπίδου εξετάζει τους ερμηνευτικούς παράγοντες της μεταβολής των εκπομπών CO_2 στην Ευρωπαϊκή Ένωση πριν και μετά την οικονομική κρίση. Τα εμπειρικά αποτελέσματα δείχνουν μία παράπλευρη αρνητική επίδραση της ύφεσης στην αποτελεσματική χρήση του περιβάλλοντος υποδηλώνοντας σημαντική αναστροφή της συμβολής των διαφόρων επεξηγηματικών παραμέτρων στην περίοδο μετά την οικονομική κρίση. Η $9^{η}$ εργασία των Νικολάου, Δακτυλα και Ευαγγελινού επανεκτιμά την επίδραση της οικονομική κρίσης στα συστήματα περιβαλλοντικής διαχείρισης στις μικρομεσαίες επιχειρήσεις. Βάσει πρωτογενούς έρευνας, τα εμπειρικά αποτελέσματα δείχνουν ότι αν και η οικονομική κρίση μπορεί να κάνει κάποιες επιχειρήσεις απρόθυμες στην υιοθέτηση συστημάτων περιβαλλοντικής διαχείρισης, παρά ταύτα η τρέχουσα περιβαλλοντική νομοθεσία μπορεί να ισορροπήσει αυτή την τάση και να προωθήσει την εφαρμογή τους.

Οι επόμενες εννέα εργασίες ασχολούνται με τη χρήση Ποσοτικών Μεθόδων στην Οικονομική των Φυσικών Πόρων και του Περιβάλλοντος. Η $10^{η}$ μελέτη των Νάστη και Μάττα ασχολείται πειραματικά με την εκμάθηση και επεξήγηση της δυναμικής της κλιματικής αλλαγής και με τη βοήθεια ενός δυναμικού προσομοιωτή κλιματικής αλλαγής (Dynamic Climate Change Simulator) που είναι μια απλούστευση του πολύπλοκου κλιματικού συστήματος στα βασικά συστατικά της συγκέντρωσης CO_2, των ανθρωπογενών εκπομπών CO_2 και στη φυσική απορρόφηση CO_2 στην ατμόσφαιρα. Η $11^{η}$ εργασία των Κατρακυλίδη, Κυρίτση και Πάτσικα, βάσει ετήσιων στοιχείων για την περίοδο 1960–2012 και τη χρήση οικονομετρικών μεθόδων, ασχολείται με τις δυναμικές αιτιώδεις και μη σχέσεις μεταξύ εκπομπών CO_2, ενεργειακής κατανάλωσης και μεγέθυνσης στη χώρα μας.

Η $12^{η}$ εργασία των Κεβόρκ και Χάλκου παρουσιάζει τα διαστήματα εμπιστοσύνης των εκατοστημοριών στην περίπτωση μιας στάσιμης διαδικασίας ARMA και με εφαρμογή στις ετήσιες εκπομπές CO_2 για τη χρονική περίοδο 1960-2012. Η $13^{η}$ εργασία των Μάρκου, Μιχαηλίδη, Λοΐζου και Μάττα εξερευνά θέματα σχετικά με την κλιματική αλλαγή και τους υδάτινους πόρους και τη γεωργία στην Κύπρο. Αυτό επιτυγχάνεται με τη βοήθεια της μεθόδου της υποθετικής αγοράς για την αποτίμηση του περιβάλλοντος και την εκτίμηση της προθυμίας πληρωμής καθώς και της μεθόδου Delphi.

Οι επόμενες εργασίες επικεντρώνονται στη Θεωρία Παιγνίων. Η 14η εργασία των Χάλκου και Παπαγεωργίου μελετά τη δυναμική της ρύπανσης και την πιθανότητα αστάθειας και κύκλων, καταλήγοντας μεταξύ άλλων ότι παίρνοντας το απλό υπόδειγμα ρύπανσης ενός σταδίου με μία μεταβλητή ελέγχου και επεκτείνοντας σε μεταβλητές δύο σταδίων, η ισορροπία ενδέχεται να αλλάξει με το ρυθμό άριστων εκπομπών ρύπων να είναι κυκλικός. Η 15η εργασία των Μανούση και Ξεπαπαδέα εξετάζει τη ρύθμιση της κλιματικής αλλαγής με τη χρήση γεωμηχανικών μεθόδων όταν οι χώρες παρουσιάζουν ετερογένεια. Για το σκοπό αυτό μελετήθηκε ένα απλό δυναμικό παίγνιο σχεδιασμού άριστης πολιτικής σε όρους εκπομπών ρύπων και γεωμηχανικών προσπαθειών. Η 16η εργασία των Κουτσούμπα και Καμπά εξετάζει το θέμα της κατανομής δικαιωμάτων αλίευσης για τη διαχείριση του Μεσογειακού τόνου. Η 17η εργασία των Καρκατσούλη, Παρούσσου, Φράγκου και Κάπρου χρησιμοποιώντας ένα υπόδειγμα γενικής ισορροπίας εκτιμά το πλεονέκτημα της πρώτης κίνησης στην πολιτική για την κλιματική αλλαγή. Συγκεκριμένα αναλύονται τα μακροοικονομικά κόστη και οφέλη για την ΕΕ ως ο ηγέτης (first mover) στον έλεγχο της κλιματικής αλλαγής. Τέλος η 18η εργασία των Χάλκου και Τσιλίκα προτείνει ένα υπόδειγμα ανάλυσης και απεικόνισης των συνεργιστικών μηχανισμών επίδρασης των σχετικών με την κλιματική αλλαγή κοστών.

Οι επόμενες πέντε εργασίες ασχολούνται με την εκτίμηση των περιβαλλοντικών επιπτώσεων. Η 19η εργασία των Κόλλια και Παπαδάμου εξετάζει με οικονομετρική υποδειγματοποίηση την αντίδραση των επενδυτών σε φυσικές και ανθρώπινης προέλευσης καταστροφές. Η 20η εργασία του Χ. Κίτσου αναφέρεται στα πυρηνικά ατυχήματα και στις κοινωνικοοικονομικές τους επιπτώσεις. Η 21η εργασία της ενότητας αυτής από τους Καζαμία, Παπακωνσταντίνου και Κασσιό προτείνει ένα σύστημα αξιολόγησης για μελέτες περιβαλλοντικών επιπτώσεων με προδιαγραφή και δημιουργία ενός αλγόριθμου ποιότητας. Η 22η μελέτη των Αγγελάκογλου και Γκαϊντατζή αναλύει τα στοιχεία τα οποία μια βιομηχανία θα πρέπει να στοχεύει να αποκτήσει ώστε να βελτιώσει την περιβαλλοντική της βιωσιμότητα βάσει των αρχών της Βιομηχανικής Οικολογίας για την αποτίμηση της περιβαλλοντικής βιωσιμότητας των επιχειρήσεων, Τέλος η 23η εργασία των Σκριμιζέα, Παπακωνσταντίνου και Παπαδοπούλου προτείνει μία στρατηγική προσαρμογής στην Κλιματική Αλλαγή ως εργαλείο ικανό να διαχειριστεί, την κατάλληλη προσαρμογή του σχεδιασμού του ελληνικού χώρου αλλά και την απαραίτητη ανάπτυξη συνεργασίας των διαφόρων επιστημονικών πεδίων και κλάδων που εμπλέκονται στο πολυδιάστατο αυτό πρόβλημα.

Οι επομένες μελέτες αφιερώνονται στις Επιχειρήσεις και το Περιβάλλον και την Εταιρική Κοινωνική Ευθύνη. Η 24η εργασία των Σταυροπούλου, Κωστάκη και Σαρδιανού εξετάζει τους προσδιοριστικούς παράγοντες που καθορίζουν τις αντιλήψεις των καταναλωτών απέναντι στην εταιρική κοινωνική ευθύνη με έμφαση στις περιβαλλοντικά φιλικές στρατηγικές. Η 25η εργασία των Σεπετή και Ρίζου αναφέρεται εκτενώς στην εταιρική κοινωνική ευθύνη και στις πολιτικές περιβαλλοντικής διαχείρισης με αναφορά στα Τεχνολογικά Εκπαιδευτικά Ιδρύματα της χώρας μας. Η 26η εργασία των Μεταξά και Τσαβδαρίδου εξετάζει τον τρόπο με τον οποίο η κλιματική αλλαγή ερμηνεύεται στις αναφορές εταιρικής κοινωνικής ευθύνης των Ελληνικών επιχειρήσεων. Η 27η εργασία της ενότητας από την Μ. Μαρκάτου συζητά τον τρόπο αντίδρασης των Ελληνικών επιχειρήσεων στο εθνικό κάλεσμα για πράσινη επιχειρηματικότητα.

Στις ίδιες γραμμές, οι επόμενες μελέτες αναφέρονται στην πράσινη οικονομία, τη βιωσιμότητα και την καινοτομία. Η 28η μελέτη των Σκουλούδη, Μαλέσιου, Jones και Ευαγγελινού εξερευνεί την επιχειρηματική περιβαλλοντική λογιστική σε σχέση με την κλιματική αλλαγή και δείχνοντας σε τι επίπεδο οι Ελληνικές επιχειρήσεις καταγράφουν και αποκαλύπτουν περιβαλλοντικές πληροφορίες. Η 29η εργασία των Μαρκάτου και Σταμπουλή μελετά και μετρά το προϊόν της αειφορικής καινοτομίας στις χώρες του ΟΟΣΑ. Τα αποτελέσματα βασίζονται στην καταγραφή πατέντων και τη χρήση τους ως δείκτες καινοτομικών προϊόντων. Η 30η μελέτη των Χάλκου, Τζερεμέ Ν. και Κουρτσίδη, με τη βοήθεια της προσέγγισης ενός προσθετικού δύο σταδίων DEA, ασχολείται με τους δείκτες περιφερειακής αειφορικής αποδοτικότητας στην Ευρώπη. Η 31η εργασία των Σταμπουλή και Γεωργατζή εξετάζει τις συνθήκες κάτω από τις οποίες οι διάφορες πολιτικές ενθαρρύνουν τις οικο-καινοτομίες ενώ κατηγοριοποιούνται τα εμπόδια που ενδέχεται να ανακύψουν κατά την υιοθέτηση τους.

Οι επόμενες πέντε εργασίες αναφέρονται στην αστική και περιφερειακή Ανάπτυξη και το περιβάλλον. Η 32η εργασία των Χάλκου και Τζερεμέ Ν. αναφέρεται στην περιφερειακή περιβαλλοντική αποδοτικότητα σε σχέση με την οικονομική μεγέθυνση και την αύξηση του πληθυσμού και με τη χρήση της μεθόδου της δεσμευμένης range directional συνάρτησης απόστασης. Η 33η εργασία των Σοφίου, Παπακωνσταντίνου και Κασσιού αναφέρεται στην αστικοποίηση στην Ανατολική Μεσόγειο και τις επιδράσεις της στην ατμοσφαιρική ρύπανση, το κλίμα και το οικοσύστημα και με αναφορά στην περίπτωση του Λεκανοπεδίου Αττικής. Για το σκοπό αυτό η μελέτη αναφέρεται στους ρύπους από την Αθήνα, το Κάιρο και την Κωνσταντινούπολη που επηρεάζουν το κλίμα της ανατολικής Μεσογείου. Βαρύτητα δίνεται στις κλιματικές αλλαγές από την βεβαρημένη δόμηση των πόλεων και τη δημιουργία αστικών νησίδων στις μεγαλουπόλεις της Μεσογείου με ειδική αναφορά στην Αθήνα. Η 34η εργασία των Γαλάνη Α. και Ηλιού αναλύει την Ευρωπαϊκή και Ελληνική πολιτική για δημιουργία βιώσιμου αστικού περιβάλλοντος δίνοντας ιδιαίτερη προσοχή στις βιώσιμες αστικές μετακινήσεις. Επίσης παρουσιάζονται διάφοροι αειφορικοί δείκτες των πόλεων, καθώς και δείκτες αποτίμησης αυτής της βιώσιμης κινητικότητας. Η 35η εργασία των Αρβανιτίδη και Νασιώκα διερευνά τη συλλογική διαχείριση των υπόγειων υδάτων στην περιοχή της Λάρισας και αναπτύσσει το εννοιολογικό πλαίσιο για τη μελέτη των υπογείων υδάτων ως κοινών πόρων. Στις γραμμές αυτές αξιολογεί εμπειρικά τη δυνατότητα συλλογικής δράσης των χρηστών των υπόγειων υδάτων για αρδευτικούς σκοπούς και απαντά στο ερώτημα του αν τα ζητήματα της διαχείρισης υπόγειων υδάτων στην περιφγέρεια της Θεσσαλίας είναι τραγωδία ή ευκαιρία. Τέλος η 36η εργασία των Οικονόμου και Ράπτη διερευνά και εξετάζει οικονομετρικά τις επιδράσεις ατομικών και μακροοικονομικών παραγόντων στην ατομική υποκειμενική ευημερία.

Η επόμενη ενότητα μελετών ασχολείται με την Οικονομική Αξιολόγηση του Περιβάλλοντος. Η 37η εργασία των Jones, Clark, Μαλέσιου και Ευαγγελινού εξετάζει με πρωτογενή έρευνα την επίδραση των παραμέτρων του κοινωνικού κεφαλαίου στην προθυμία πληρωμής για την προστασία της παράκτιας ζώνης στη Νότιο-Ανατολική Αγγλία. Η $38^η$ εργασία των Κουντούρη και Dávila προτείνει μία ολοκληρωμένη κοινωνικο-οικονομική προσέγγιση και αποτίμηση για την εφαρμογή της Ευρωπαϊκής Οδηγίας Πλαίσιο για τα Ύδατα στην Ελλάδα. Η $39^η$ εργασία των Δαμίγου, Κοντογιάννη, Τουρκολιά, Σκούρτου, Ανδρεάδη και Βελεγράκη παρουσιάζει ένα σύγχρονο πλαίσιο διαχείρισης στην αποτίμηση των πολιτικών προσαρμογής στην μέση αύξηση της στάθμης της θάλασσας. Η $40^η$ εργασία των Φ. Κουντούρη, Ε.Β. Κουγέα κ.ά. με τη χρήση της μεθόδου διαμόρφωσης επιλογών αποτιμά τις οικονομικές αξίες που δημιουργούνται από τις βελτιώσεις στην ποιότητα των υδάτων και κατ' επέκταση του περιβάλλοντος. Η μελέτη περίπτωσης αναφέρεται στη περιοχή Rokua στη Βόρεια Φιλανδία μία περιοχή εξαρτώμενη από τα υπόγεια ύδατα και πολύ ευαίσθητη στην κλιματικές αλλαγές και τις φυσικές μεταβολές.

Οι επόμενες εργασίες αφορούν τη βιοπικοιλότητα, το βιώσιμο τουρισμό, και τις βιώσιμες μεταφορές. Η $41^η$ εργασία των Οικονόμου, Νεοφύτου και Ματσιώρη εξετάζει εμπειρικά τα κίνητρα σχεδιασμού τουριστικών γεγονότων παρέχοντας ευρήματα χρήσιμα για τη διαχείριση και την προώθηση αειφορικών και αποτελεσματικών από πλευράς κόστους τουριστικών πολιτικών. Η $42^η$ μελέτη των Ματσιώρη, Βαρσαμούση, Εξαδάκτυλου και Βαφείδη προσδιορίζει τους παράγοντες απόδοσης οικονομικής αξίας στη θαλάσσια βιοποικιλότητα εκτιμώντας τη μέση προθυμία πληρωμής για τη διατήρησή της. Η $43^η$ εργασία των Προφυλλίδη και Μποτζώρη προσεγγίζει την κλιματική αλλαγή και τις επιδράσεις των μεταφορών σε παγκόσμιο αλλά και εθνικό επίπεδο. Η $44^η$ εργασία των Γαλάνη Α., Μποτζώρη και Ηλιού βασιζόμενη σε αποτελέσματα πρωτογενούς έρευνας, προτείνει πολιτικές επίτευξης βιώσιμων μεταφορών και μείωσης του θορύβου από την κυκλοφοριακή συμφόρηση με αναφορά στην πόλη του Βόλου. Οι πολιτικές αυτές μπορούν να βελτιώσουν τα ποιοτικά χαρακτηριστικά διαβίωσης των ανθρώπων στα αστικά κέντρα και μάλιστα στην οικονομική κρίση που διανύουμε. Τέλος η $45^η$ εργασία του Σ. Ταμπέκη παρουσιάζει τους οικονομικοτεχνικούς παράγοντες επίτευξης βιώσιμης ανάπτυξης και επηρεασμού των έργων διάνοιξης του δάσους στην περιοχή του Μετσόβου.

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Άρθρα Συνεδρίου

An analysis of long-term scenarios for the transition to renewable energy in Greece*

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Abstract

The climate and energy package known as the "20-20-20" targets is a set of binding legislation which aims to ensure the European Union meets its ambitious climate and energy targets for 2020. The Commission proposes a new objective of increasing the share of renewable energy to at least 27% of the EU's energy consumption by 2030. In combination with European and national targets the key objective of this work is to construct scenarios for the carbon intensive Greek energy system and to investigate how are reflected in both economic and environmental terms. The tool used in the scenario analysis is the Long range Energy Alternatives Planning System (LEAP). The assembly of the model for evaluating energy scenarios in Greece and the results of these policy-based scenarios are described. Furthermore, the impacts of energy supply and demand are explored, along with their implications for national long-term policy plans.

Keywords: Climate change; Renewable energy sources; Greek energy system.

JEL κωδικοί: Q20; Q40; Q41; Q42; Q54.

* Work in this research has received funding from the "GHGsMETI" program, which takes place within the **SYNERGASIA 2011** action and is supported by the European Regional Development fund and Greek National Funds, project number **11SYN_8_118**. The text represents the authors' views.

ΕΥΡΩΠΑΪΚΗ ΕΝΩΣΗ
ΕΥΡΩΠΑΪΚΟ ΤΑΜΕΙΟ ΠΕΡΙΦΕΡΕΙΑΚΗΣ ΑΝΑΠΤΥΞΗΣ

ΑΝΤΑΓΩΝΙΣΤΙΚΟΤΗΤΑ ΕΠΙΧΕΙΡΗΜΑΤΙΚΟΤΗΤΑ
ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΠΑΝ ΙΙ
η περιφέρεια στο επίκεντρο της ανάπτυξης

ΕΣΠΑ 2007-2013
πρόγραμμα για την ανάπτυξη

Υπουργείο Παιδείας και Θρησκευμάτων
ΕΥΔΕ-ΕΤΑΚ

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1. Introduction

An important issue for public health, economy and the environment is air quality that is negatively related to climate change. Although various policies have been implemented in national and sectoral level, air pollution continues to pose a threat to human health and affect the economy and the environment. However, Europe under the framework of integrated policies, has achieved to reduce emissions of various air pollutants and substances such as sulphur dioxide (SO_2), carbon monoxide (CO), benzene (C_6H_6) and lead (Pb) (European Environment Agency, 2013).

In 2007, targets were set in order to develop an energy efficient and low carbon Europe. These targets, known as the "20-20-20" targets include:

- A 20% reduction in EU greenhouse gas emissions from 1990 levels;
- An increase in the share of EU energy consumption produced from renewable resources to 20%;
- A 20% improvement in the EU's energy efficiency.

Moreover, in 22 January 2014, an integrated policy framework for the period up to 2030 was presented towards a renewable energy economy as the share of renewable energy sources is set to increase by at least 27% till 2030.

The Greek government in an effort to adopt a green economy has included ambitious policies and measures for increasing the use of renewable energy. Specifically, Law 3851/2010 sets the framework for the deployment of renewable energy. The government tries to ensure that the 2020 European targets are met. The development of renewable energy sources in the electricity sector is of crucial importance to achieve the National and European objectives. The overall target of 20% participation of Renewable Energy Sources (hereafter **RES**) in gross final energy consumption is composed of 40% participation of RES in electricity production, 20% in heating and cooling and 10% in transport.

Additionally, it is necessary to make investments in the electricity sector and exploit the potential of wind and solar energy. An important development is to connect Greek islands with abundant wind and solar power potential to the mainland transmission network and to expand hydropower and natural gas capacity (IEA/OECD, 2011).

At national level the energy sector is very important for economic development. From an environmental perspective, the energy sector in Greece can be characterized by the inefficient use of energy, the small reduction of greenhouse gas emissions as well as the slow replacement of conventional fuels (like lignite). Nevertheless, many actions have been initiated in order to comply with EU policies on the management of energy by looking for improvements over the national legal framework considering the production and consumption of energy. Furthermore, Renewable Energy in Greece is at a relatively high level of capacity utilization, particularly in the most prevalent forms, following the global and European trend and creating a national strategy (European Environment Agency, 2012; p. 178).

The remainder of this paper is structured as follows. In Section 2, we explore the basics concerning the penetration of renewable energy sources in the Greek energy system and specifically in the electricity generation sector, providing information for the existing legislative framework. Section 3 presents the Long range Energy Alternatives Planning system (LEAP), the proposed scenarios and the basic key assumptions. Section 4 comments on and analyzes the results of the simulation output, emphasizing the technical, environmental and economic implications. Finally, the last section summarizes our main findings.

2. Background

RES constitute a cost-effective solution for the energy sector, the society and the environment offering in terms of energy supply much more friendly solutions compared to conventional fossil fuels. Energy independence, geographical dispersion and diversity of the primary forms of energy are some of the reasons that are evaluated and included in government planning of many countries worldwide. In economic terms, the use of RES while depending on the economic prosperity of the country, has further a long-term perspective even during a financial crisis. Although, greenhouse gas mitigation strategies are generally considered costly, the renewable energy and more efficient conversion technologies may have positive socioeconomic effects, create employment and lead to increase in exports (Mathiesen et al., 2011).

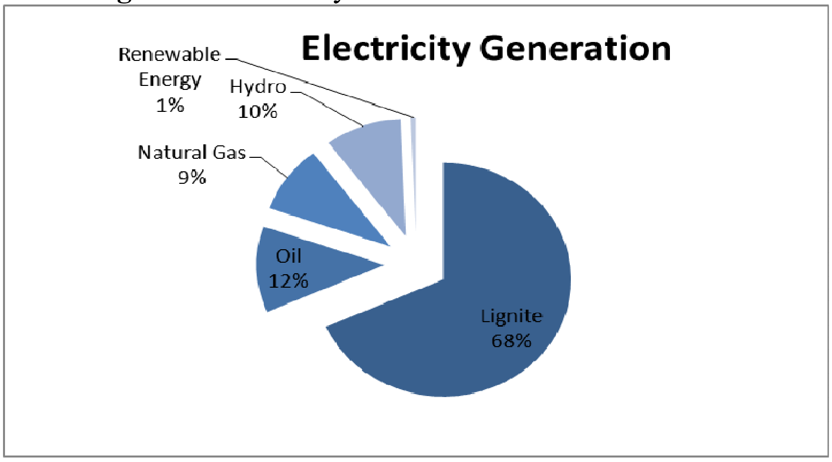
The Greek Ministry of Environment, Energy and Climate Change confirms the negative effects of climate change the solution of which is one of the key priorities. At regional level, actions required to address climate change must involve a change of the current growth model towards a sustainable, green economy and low or zero carbon emissions through the use of modern technology. The low carbon model should be based on horizontal coordination of mitigation policies that will be implemented in the sectors of energy, industry, transport and agriculture. The Greek Action Plan for Greenhouse Gases Abatement includes the decarbonisation of the Greek energy system by introducing low carbon sources or RES (IEA/OECD, 2011). The Greek renewable energy policy follows EU requirements such as the binding target to increase the share of renewable energy in gross final energy consumption by 2020. The government plans to reach the 2020 renewable energy targets through a combination of measures on energy efficiency and renewable energy[1].

Greece as a developed country has a relatively high energy demand, considering its size, and an above the average consumption per capita. The country's population, according to the census of 2011, reached a total of 10,815,197 inhabitants, placing Greece marginally outside of the ten most populous European countries, but ahead of several major economies which affects the energy demand ranking (Hellenic Statistical Authority, 2012; Marcu, 2011). Energy production in Greece is dominated by the Public Power Corporation (PPC) which holds the biggest share in the supply of electricity. In Figure 1 and for the year 2012, it is shown that the biggest share of electricity generation by PPC came from lignite (68.4%), oil (11.9%), natural gas (9.4%), hydro (9.7%) and renewable energy (0.6%) (Public Power Corporation S.A., 2012). The category hydro represents the large scale

[1] Policies and measures are described in detail in Ministry of Environment, Energy and Climate Change (2010).

hydropower projects while the renewable energy category includes photovoltaic, biomass, small scale hydropower projects and wind parks.[2]

Figure 1: Electricity Generation in Greece in 2012



2.1. Legislative framework

According to Law 3851/2010 on the acceleration in the development of RES to deal with climate change and other provisions relating to the jurisdiction of the Ministry of Environment, Energy and Climate Change, the Greek government, proceeded to increase the national goal for participation of RES in final energy consumption to 20%, which specializes in 40% participation of RES in electricity, 20% in heating and cooling needs and 10% in transport (Ministry of Environment, Energy and Climate Change, 2012a).

Considering the economic part of Law 3851/2010, new electricity pricing for the main categories has been submitted and is analyzed in Table 1. The aforementioned Law is an important part of the National Action Plan for Renewable Energy, which taking into account the standards of the European Energy Policy, is prepared to be able to "play the role of a potential tool for monitoring national energy goals" (Ministry of Environment, Energy and Climate Change, 2012a; Law, 3851/2010).

Concerning the energy savings field, Greece has already implemented the 1st Energy Efficiency Action Plan, which provides 9% of energy savings in final energy consumption by the year 2016 in accordance with Directive 2006/32/EC. Moreover, in the context of Law 3855/2010, which has been added to the recent regulation on energy performance of buildings, there is advancement in the development of market mechanisms and implementation of specific measures and policies aimed at achieving this national goal (Ministry of Environment, Energy and Climate Change, 2012a).

The Ministerial Decree 19598/01.10.2010 posed the desired ratio of installed capacity and the distribution in time of the various renewable energy technologies. The main characteristic of this Ministerial Decree is the liberation from the constraints of Geothermal Energy, as well as its participation in the electricity production of the country in

[2] According to annual report of Public Power Corporation in 2012, hydropower projects can be divided into small and large scale hydropower projects. Small scale hydropower projects are referred as renewable energy resource in contrast to large-scale hydropower projects.

the forthcoming years. Besides, in the framework of the interpretative Circular 26928/16.12.2010 some amendments have been implemented, concerning the examination of requests for the installation of Renewable Source power plants on agricultural land of high productivity, including the category of professional farmers (Circular 26928/2010; Ministerial Decree 19598/2010). Finally in 2011 the Joint Ministerial Decree 28287/12.12.2011 posed a special fee and incentives to household consumers in areas where renewable energy technologies had been installed (Common Ministerial Decree 28287/2011).

Table 1: Electricity power pricing of key Renewable Energy Sources (Greece)

Generating electricity from:	**Energy Price (€ / MWh)**	
	Interconnected system	**Non-interconnected islands**
Wind energy exploited in onshore power installations greater than 50 KW.	87,85	99,45
Wind energy utilized to power installations less than or equal to 50 KW.	250	250
Photovoltaics to 10 KW in the residential sector and small businesses.	550	550
Hydraulic energy utilized by small hydropower stations with installed capacity up to 15 MW.	87,85	87,85
Solar energy utilized by solar thermal power plants.	264,85	264,85
Solar energy utilized by solar thermal power plants with storage system at least two hours.	284,85	284,85
Geothermal Energy low enthalpy (Law 3175/2003).	150	150
Geothermal Energy high enthalpy (Law 3175/2003).	99,45	99,45
Biomass is used by stations ≤ 1 MW.	200	200
Biomass harvested from plants > 1 MW and ≤ 5 MW	175	175
Biomass is used by stations > 5 MW.	150	150

Source: Modified and relying on Law 3851/2010

2.2. Renewable Energy Sources

The Wind Energy in Greece is at a high level, with a large number of wind turbines and a significant total installed capacity corresponding to approximately 1800 MW. Furthermore, there are prospects and estimations for the coming years, which are quite encouraging in accordance with the upward trend in recent years. From 1998 and onwards the growth in wind power is quite high and has not declined during the outbreak and the early years of the global financial crisis (HWEA, 2013).

The wind potential in Greece is quite remarkable, having in several parts of the country average wind speeds that are economically exploitable. The highest wind speed is greater than 10 meters per second (m/s) and is located at the southern part of Evia (east of Karystos), in Skyros, Andros, Laconia, Amorgos, western Samos, in the southwestern island of Rhodes, Karpathos and eastern Crete. Speeds 9 to 10 m/s are found in all islands of the Aegean Sea, south Evia, Corfu, Kefalonia, in southern Attica and in scattered parts of Greece. Offshore wind farms in Greece like in most Mediterranean countries are inferior to the first theoretical steps beginning in 2010. The areas of Alexandroupolis, Thassos, Corfu, Kimi, Lemnos and Samothrace were selected to be included to Wind Energy development projects. The horizon for the first development phase of projects in these areas, was determined to be five years from 2012 to 2017, but at the end of 2012 no project was implemented (Ministry of Environment, Energy and Climate Change, 2011; 2012b).

Analyzing the total installed wind power of Greece in the individual regions of the country, it becomes apparent that Central Greece is leading the largest share of production. The total installed capacity of the regions of Peloponnese, Eastern Macedonia and Thrace, Crete and Western Greece, is greater than 100 MW (HWEA, 2013).

The Solar Energy in Greece is expanded with very high growth rates in recent years, mainly in the category of photovoltaic (PV) systems. It is characteristic that from 2009 to 2010 the total installed capacity of PV systems almost fivefold and from 2010 to 2011 tripled while from 2011 to 2012 more than doubled. Still, PV systems are the locomotive of Renewable Sources in Greece, accounting for 88% of new capacity in 2012 (Hellenic Association of PV Companies, 2013).

The solar potential of Greece is one of the best in the European Union, along with the other Mediterranean countries. The location of the country and place between 340 and 420 parallel of the northern hemisphere, gives a mild Mediterranean climate suitable for systems operating with solar radiation. The maximum average potential, measurable with a photovoltaic system of 1 KW is located in the Dodecanese, the Cyclades, Crete, the Sporades, the East Aegean Islands, Attica, in south Central Greece, in the eastern Peloponnese and Western Macedonia.

In contrast, the lowest rates are located in the north and in eastern Macedonia and Thrace. The exploited potential of the country has rocketed in recent years of only 10,3 MW in 2008 to 1.536 MW in 2012 and 1.862,5 MW as in February 2013, with Greece in the fourth position in Europe and seventh internationally in new PV installed capacity in 2012. In terms of participation within the country, it is estimated that the total production of solar panels, which touched the 1.7 billion kilowatt hours, covered 3% of the electricity needs of Greece in 2012. This trend shows that it is very likely that in 2013 the output of photovoltaic systems will overcome wind power for the first time (Hellenic Association of PV Companies, 2013).

Analyzing the distribution of total installed capacity in 2012 in Greece by photovoltaic systems in regions of the country we conclude that the Peloponnese is leading with Central and Western Greece to follow. In contrast, concerning the total installed capacity of photovoltaic systems on roofs of houses, the Region of eastern Macedonia and Thrace holds the primacy, with the Peloponnese and central Greece to follow (Hellenic Association of PV Companies, 2013).

Hydropower in Greece has several large, economically exploited potential, which is estimated at around 80 TWh. Until today, the rate of capacity utilization that is around 40% was derived from 16 major hydropower projects and many small which are all under the operation of the Public Power Corporation (PPC) while private investors do not participate in the production until now. Greece is a fairly mountainous country with a rich potential of waterfalls due to the configuration of the basin, but also due to several rainfalls, creating a considerable hydropower potential, quite capable of significant generation of electricity.

The active and under-construction facilities, as well as areas of interest, for large and small-scale hydropower stations respectively, are accumulated mainly in Western Greece where annual rainfall is around 260 cm. The locations where the rain gets the highest values are found in the prefectures of Ioannina, Grevena, Trikala, Arta, Karditsa, Evrytania, Phocis and Achaia (Athens Water Supply and Sewerage Company, 2010).

Unlike large-scale hydroelectric power plants, small plants, that by 2013 their total installed capacity reached only the 218 MW, have several pending applications for new stations that are in various procedural stages. Thus, there would be an increase of power in the coming years, which, due to the fact that as small-scale stations are those who have a capacity below 10 MW, is not expected to be a large-scale annual increase (Operator of Electricity Market S.A., 2012).

3. Utilization of LEAP System

The Long range Energy Alternatives Planning System (hereafter **LEAP**) is a widely-used software tool for energy policy analysis and climate change mitigation assessment developed by the Stockholm Environment Institute. LEAP has been adopted by thousands of organizations in more than 190 countries worldwide. LEAP is fast becoming the de facto standard for countries undertaking integrated resource planning, greenhouse gases (hereafter **GHG**) mitigation assessments, and Low Emission Development Strategies (LEDS) especially in the developing world. Many countries have also chosen to use LEAP as part of their commitment to report to the United Nations Framework Convention on Climate Change (UNFCCC).

There are various studies in Greece that have been conducted in order to provide the literature with long-term projections in the energy sector using LEAP. Giatrakos et al. (2009) evaluated the present electrical energy status, and examine the possibility of further penetration of sustainable energy for Crete. Analysis shows that even the most modest and realistic RES implementation scenarios, combined with a partially successful demand restriction, could indeed contract the island's environmental footprint. RES penetration into Crete's electric system seems to be able to surpass 30% by 2020, satisfying even the optimistic European targets. Roinioti et al. (2012) constructed energy scenarios for the future with a focus on the Greek electricity production system and explore how these scenarios are reflected in economic and environmental terms as well as in terms of energy efficiency.

Papagiannis et al. (2008) present the results of an analysis on the economic and environmental impacts of the application of an intelligent demand side management system, called the Energy Consumption Management System (ECMS), in the European countries. The long-term impacts following the application of the system are evaluated using the LEAP platform. Results show that under a reasonable market penetration, a reduction of 1–4% in primary energy, of 1.5–5% in CO_2 emissions and a 2–8% savings in investment costs for power generation expansion is to be expected for the EU-15.

3.1 Construction of scenarios

Scenarios are self-consistent story lines of the evolution of future energy systems in the context of a specific set of conditions. Scenarios assemble information about different trends and possibilities into internally consistent images of plausible alternative futures (Wiseman et al., 2011; Carter, 2007; Moss et al., 2010). The main concept of LEAP is an end-use driven scenario analysis with a baseline and alternative scenarios. The scenarios are used for a number of "what if" questions under the arrangement of user-defined assumptions. The set of conditions is detailed in the scenarios and are constructed in order to encompass some factors (parameters) that are anticipated to change.

In our case there are three scenarios generated under different options. The policy options and key assumptions that the scenarios are based are depicted in Table 2. That is:

Baseline Scenario: The first scenario is the "Baseline", which is based on historical trends from 1990 till 2010. Changes in demographic and macroeconomic variables are given in Table 3. Specifically, Table 3 describes the projections for the annual population growth rate, annual GDP growth rate, annual growth rate of income and the annual growth rate of GDP per capita till the target year 2030 (Ministry of Environment, Energy and Climate Change, 2013). The projected potential withdrawals of Power Plants are given in Table 4 (Ministry of Environment, Energy and Climate Change, 2013).

Target 2020 Scenario: The second scenario is based on the European target set in 2007, in order to develop an energy efficient and low carbon Europe via an increase in the share of EU energy consumption produced from renewable resources to 20%. According to the government, Law L3851/2010 states that the protection of the climate or the reduction of GHG emissions through the promotion of electrical energy production from RES is a crucial element of the energy sector of the country. The further specific targets include RES electricity share (40%), RES heating and cooling share for the household sector (20%), and RES transport share (10%) in order to achieve the national target of 20% contribution of the energy produced from RES to the gross final energy consumption. This target will be achieved through the large penetration of RES technologies in electricity production, heat supply and transport sector.

The changes in demographic and macroeconomic variables that are used *in target 2020 scenario* are given in Table 3, as for the *Baseline scenario*. Finally, we assume a 50% increase of RES capacity, which corresponds to 5.311,7 MW. Specifically, as the Hellenic Transmission System Operator S.A. publishes binding and final Offers for Connection System or Network for power stations of Renewable Energy and Stations and cogeneration plants of Electricity & Heat and High Performance (CHP), we assume that till 2020 will be achieved half of the non binding offers. Table 5 describes in details the structure of the assumed generated capacity per RES category.

Target 2030 Scenario: We follow the target set in 22 January 2014 by the European Commission towards a renewable energy economy. Specifically, the share of renewable energy penetration in final consumption is set to increase at least 27% by 2030. This will be achieved by the introduction of RES in industry. Following Heaps et al. (2009) concerning the industry sector, CO_2 emissions can be further reduced through the increased use of biomass, natural gas and increased participation of RES in electricity, the iron and steel production sector, the cement production, chemicals production and other industrial subsectors. As far as the changes in demographic and macroeconomic variables that are used in *target 2030 scenario* these are given in Table 3, as for the *Baseline* and *target 2020 scenarios*.

Finally, we assume a 100% increase of RES capacity, which corresponds to 10.536,2 MW. Specifically, as in the previous scenario and relying on the Hellenic

Transmission System Operator S.A., the last column of Table 5 describes in details the structure of the assumed generated capacity per RES category.

Table 2: Policy options and assumptions for scenario generation

Scenario	Policy options	Assumptions
Baseline		The historical trends will continue. Changes in demographic and macroeconomic variables are given in Table 3 and potential withdrawals of Power Plants are given in Table 4.
Target 2020	European target: 20 % penetration of RES in final consumption till 2020. Greek Government target: The enactment of Law 3851/2010 RES specializes in a 40 % increase of electricity, 20% increase of the thermal RES and 10 % increase of biofuels.	Changes in demographic and macroeconomic variables are given in detail in Table 3 and the potential withdrawals of Power Plants are given in detail in Table 4. Increase of Renewable Sources utilization up to 5.108 MW is presented in details in Table 5
Target 2030	European target: 27% increase of RES penetration in final consumption in 2030. This will be achieved by the introduction of RES in industry.	Changes in demographic and macroeconomic variables are given in Table 3 and potential withdrawals of Power Plants are given in Table 4. Increase of Renewable Sources utilization up to 10.216 MW is presented in details in Table 5

Table 3: Changes of demographic and macroeconomic variables till 2030.

	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Annual population growth rate	0,1%	0,0%	-0,2%	-0,2%	-0,1%	-0,3%	-0,2%
Annual GDP growth rate	-4,0%	-2,6%	1,1%	2,1%	2,1%	2,6%	2,6%
Annual growth rate of income	-4,0%	-3,7%	0,8%	2,8%	2,5%	2,6%	2,6%
Annual growth rate of GDP per capita	-9,0%	-2,0%	0,9%	1,8%	1,6%	2,6%	2,6%
	2018	**2019**	**2020**	**2025**	**2030**		
Annual population growth rate	-0,1%	-0,1%	-0,2%	-0,2%	-0,4%		
Annual GDP growth rate	2,5%	2,5%	2,9%	2,2%	1,5%		
Annual growth rate of income	2,5%	2,5%	2,9%	2,2%	1,5%		
Annual growth rate of GDP per capita	2,5%	2,5%	2,9%	2,2%	1,5%		

Source: Ministry of Environment, Energy and Climate Change (2013)

Table 4: Projected potential withdrawals of power stations

Withdrawal of Power Units	Power Output (MW)	Power Units	Fuel
2011	64	Ptolemaida 1	Lignite
2011	113	Megalopoli 1	Lignite
2011	113	Megalopoli 2	Lignite
2012	117	Ptolemaida 2	Lignite
2012	33	Liptol	Fuel oil
2013	144	Aliveri 3	Fuel oil
2013	145	Aliveri 4	Fuel oil
2014	145	Laurio 1	Fuel oil
2014	285	Laurio 2	Fuel oil
2014	173	Laurio 3	Natural Gas
2014	117	Ptolemaida 3	Lignite
2015	153	Ag. Geor. 8	Natural Gas
2015	185	Ag. Geor. 9	Natural Gas
2015	276	Ptolemaida 4	Lignite
2019	275	Kardia 1	Lignite
2019	275	Kardia 2	Lignite
2019	300	Kardia 3	Lignite
2019	275	Kardia 4	Lignite
2019	273	Amintaio 1	Lignite
2019	273	Amintaio 2	Lignite
2022	274	Ag. Dimitrios 1	Lignite
2022	274	Ag. Dimitrios 2	Lignite
2022	283	Ag. Dimitrios 3	Lignite
2022	283	Ag. Dimitrios 4	Lignite
2024	260	Megalopoli 4	Lignite
2024	270	Megalopoli 3	Lignite

Source: Ministry of Environment, Energy and Climate Change (2013)

Table 5: Generation capacity projections per RES category till 2020 and 2030

RES	Capacity (MW) 2020	Capacity (MW) 2030
Photovoltaics	207,5 MW	415 MW
Wind Park	4.666,5 MW	9.333 MW
Small Hydro	350,2 MW	640,2 MW
Biomass	87,5 MW	175 MW
TOTAL	5.311,7 MW	10.536,2 MW

http://www.desmie.gr/ape-sithya/stathmoi-ape-sithya-me-prosfora-syndesis/

3.1.1. Structure of LEAP dataset

3.1.1.1. LEAP "tree"

The LEAP "tree" in the case of Greece includes a demand dataset describing the energy use in each branch "tree'' in the base year and through 2030. It also includes various demographic and economic indicators. The sources used for energy demand data include the Hellenic Statistical Authority (El. Stat)[3], Eurostat[4], Bank of Greece[5] World Bank, and OECD[6]. The dataset depicted in Table 6, includes activities–such as number of households, economic output, fuel shares and energy intensities. The demand includes six sectors: Households, Agriculture and Fishing, Services, Industry, Transport and the Non-Energy Fuel Use. This is accompanied by various demographic and economic indicators.

Table 6: Energy Demand Structure

Sectors/ Indicators	**Sub-sectors**	**Fuel categories**	**Sources**
Households		Natural gas, solar, wind, biomass, heat, electricity, coal	El.Stat, Eurostat, World Bank, OECD
Agriculture and Fishing		Petroleum products, geothermal, electricity, biomass	El.Stat, Eurostat, World Bank, OECD
Services		Petroleum products, solar, wind, electricity, biomass, natural gas	El.Stat, Eurostat, World Bank, OECD
Industry	Iron and Steel, Chemical and Petrochemical, Non Ferrous Metals, Non Metallic Minerals, Transport equipment, Paper Pulp and Printing, Wood and Wood Products, Textile and Leather, Construction, Mining and Quarrying, Other Industry	Lignite, coal, electricity, natural gas, biomass– biogas	El.Stat, Eurostat, World Bank, OECD
Transport	Road, Rail, Domestic Aviation, Domestic Shipping, Pipelines, Other Transport	Petroleum products, electricity, natural gas, biomass– biogas	El.stat, Eurostat, World Bank, OECD
Non Energy Fuel Use		Petroleum products, natural gas	El.Stat, Eurostat, World Bank, OECD
Demographic -economic indicators	Income, Population, GDP PPP, GDP MER, IMF GDP forecast, Value added Agriculture, Industry, Services.		El. Stat, Bank of Greece, Eurostat, World Bank, OECD

As can be seen from Table 6, Households' sector fuel categories used in the model include natural gas, solar, wind, biomass, heat, electricity and coal. Agriculture and Fishing fuel categories include petroleum products, geothermal, electricity, and biomass. Services fuel categories include Petroleum products, solar, wind, electricity, biomass and natural gas. Industry is further divided into sub-sector, such as iron and steel, chemical and petrochemical, non- ferrous metals, non-metallic minerals, transport equipment, paper pulp and printing, wood and wood products, textile and leather, construction, mining and quarrying, other industry. Transport is divided into road, rail, domestic aviation, domestic shipping, pipelines, other Transport. Non Energy Fuel Use includes petroleum products and natural gas. Finally, demographic-economic indicators entail income, population, GDP PPP[7], GDP MER[8], IMF GDP forecast[9], and value added[10] in the sectors of Agriculture and Fishing, Industry and Services.

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[3] http://www.statistics.gr/
[4] http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/
[5] http://www.bankofgreece.gr/Pages/default.aspx
[6] http://www.oecd.org/
[7] GDP PPP: Gross Domestic Product at Purchasing Power Parity.

3.1.1.2. Transformation Modules

The fuel supply portion of the dataset is divided into five transformation modules: Distribution Losses, Own Use, Combined Heat and Power (CHP) Production[11], Electricity Generation and Oil Refining (see Table 7). The LEAP model of Greece includes primary resources, such as crude oil, lignite, or wind energy and secondary resources such as electricity or oil products.

Table 7: Fuel Supply dataset of Greece

Module	Process types	Fuels	Sources
Distribution Losses	Process	Electricity, natural gas	El. Stat, Eurostat, PPC[12]
Own Use	Process	Electricity, natural gas, lignite, petroleum products	El. Stat, Eurostat, PPC
CHP Production	Output Fuels	Electricity	El. Stat, Eurostat, PPC
	Process	Natural gas, lignite, oil, biomass	El. Stat, Eurostat, PPC
Electricity Generation	Output Fuels	Electricity	El. Stat, Eurostat, PPC
	Process	Natural gas, lignite, oil, biomass-biogas, wind, photovoltaic, large hydro, small hydro, geothermal	El. Stat, PPC, CRES[13], RAE[14], H.T.S.O.S.A[15]
Oil Refining	Process	Crude oil	El. Stat, Eurostat, PPC

4. Results

4.1 Baseline scenario

In the Baseline Scenario, the historical trends will continue to be the same without any change. All three scenarios take into account the economic crisis and consequent decrease in energy consumption. Figure 2 presents the total installed capacity in the Electricity sector. The changes in fuels use in Figure 2 are described in details in table 8. As can be observed the use of lignite in the electricity sector in 2020 will decrease by 22% and in 2030 by 44% compared to the use in 2010. Oil products will decrease by 18% in 2020 and by 35% in 2030. However, there will be a substantial increase in the use of natural gas, biomass, geothermal, wind, photovoltaic and small hydro energy. The category large hydro it is not included in the renewable energy resources. The international trend is to exclude large hydropower projects from the national planning due to the large construction costs and the intense deterioration of the environment (PPC, 2012;.WWF Greece, 2010).[16]

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[8] GDP MER: Gross Domestic Product using Market Exchange Rates.
[9] IMF GDP forecast: International Monetary Fund Gross Domestic Product forecast.
[10] Value Added is the value of a firm's output minus the value of intermediate goods purchased by the firm.
[11] CHP is the use of single systems for production of both electricity and power.
[12] http://www.dei.gr/
[13] http://www.cres.gr/kape/index.htm
[14] http://www.rae.gr/site/portal.csp
[15] http://www.desmie.gr/nc/en/home/
[16] Scale is important when the effect of hydropower on the environment is considered. Large-scale hydropower sources with dams are a renewable energy source (under the condition that water is preserved and does not decline) but create serious environmental problems. That is *hydropower* is considered as a RES but construction of dams in both large-scale and run of river installations has a negative effect on the aquatic ecosystem by blocking fish migration and water flows. This leads among others to reduction in fish

Without any implementation of measures to reduce primary sources of energy production in electricity sector, such as lignite, based on the current data RES share of electricity production will increase by 25% in 2020 and by 29% in 2030 as it is shown in Table 9. The total energy requirements by fuel source over the modeling period are shown in Figure 3. The RES primary energy demand increases at the expense of fossil fuels such as lignite because of the announced withdrawals of Power Stations by the Public Power Corporation. Table 10, depicts the demand energy requirements share per fuel in details as shown graphically in Figure 3. Generally, without any environmental policy to increase the share of renweable energy sources in total energy consumption, their percentages will raise up to 7,3% in 2020 and 8% in 2030.

Figure 2: Capacity projection in Electricity sector (in MW)

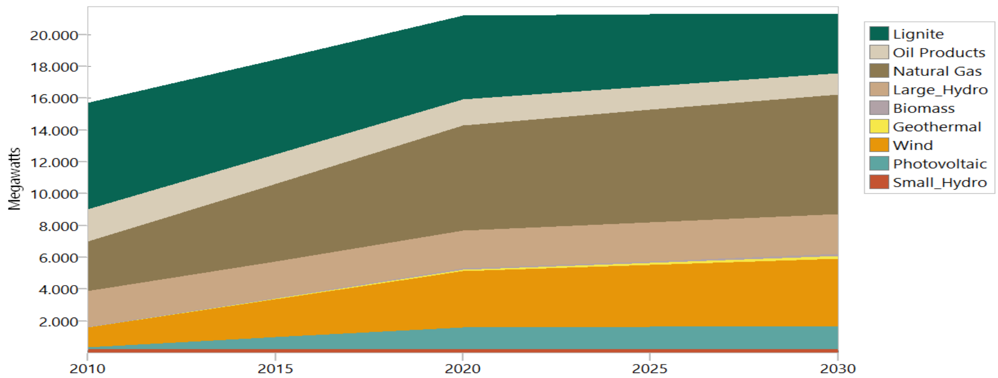

Table 8: Capacity projection in Electricity sector (in MW)

	2010	2015	2020	2025	2030
Lignite	6716	5982.3	5248.5	4514.8	3781
Oil Products	2016	1838	1660	1482	1304
Natural Gas	3123	4866.5	6610	7072.5	7535
Large_Hydro	2237	2305	2373	2441	2509
Biomass	43	63.3	83.5	100.5	117.6
Geothermal	0	24	79.3	134.7	190
Wind	1230.9	2386.3	3541.6	3885.8	4230
Photovoltaic	158.5	773	1387.5	1411.8	1436
Small_Hydro	205	211.3	217.5	223.8	230
Total	15729.4	18449.7	21200.9	21266.9	21332.6

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populations and to serious environmental problems. Small, micro- and mini-hydro installations have much lower environmental effects and in cases of areas without grid access may be an important source of electricity.

Table 9: RES share in electricity sector

	2010	2015	2020	2025	2030
RES share in electricity production (MW)	1637.4	3457.9	5309.4	5756.6	6203.6
% RES share in electricity production	10.4%	18.7%	25%	27%	29%

Figure 3: Demand Energy requirements per fuel

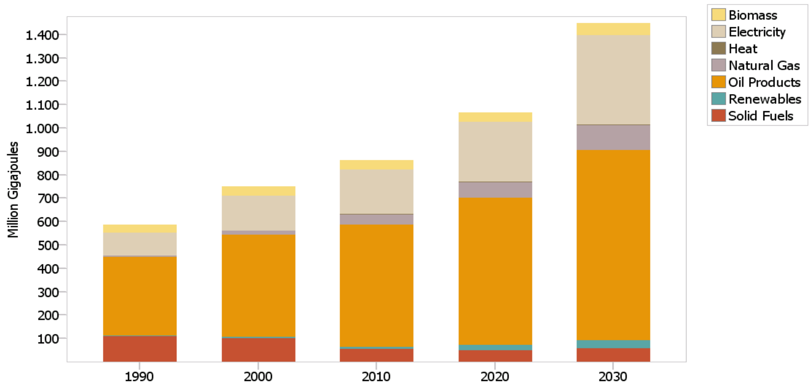

Table 10: Demand Energy requirements share per fuel

	1990	2000	2010	2020	2030
Biomass	3.5	4	4.7	5.3	5.6
Electricity	16.9	20	22.1	22.5	25.5
Heat	0	0.2	0.2	0.2	0.2
Natural Gas	0.7	2.1	5.1	6.2	7.2
Oil Products	59.7	58.7	60.6	59.1	51.2
Other Renewable	0.4	0.6	1.1	2	2.4
Solid Fuels	18.8	14.4	6.3	4.7	3.9
Total Renewable	3.9	4.6	5.8	7.3	8

4.2 Target 2020 scenario

As mentioned, the second scenario is based on the European target to develop an energy efficient and low carbon Europe via an increase to 20% in the share of EU energy consumption produced from renewable sources. The Greek government promotes the specific European targets which include RES electricity share (40%), RES heating and cooling share for household (20%), and RES transport share (10%) in order to achieve the national target of 20% contribution of the energy produced from RES to the gross final energy consumption Figure 4 shows the total installed capacity in the electricity sector till 2030. As it can be seen the use of lignite will decrease by 22% in 2020 and by 44% in 2030 compared to the year 2010 as in the baseline scenario.

The difference in this scenario is the smooth increase of energy demand for natural gas and a greater increase in mmall hydro, biomass, geothermal, wind, and photovoltaic compared to the baseline scenario as it is depicted in detail in Table 11. In Target 2020 scenario RES share in electricity sector will increase by 40.8% in 2020 and by 42,4% in

2030 as it is shown in Table 12. RES heating and cooling share (20%) and RES transport share (10%) targets are depicted in Figures 5 and 6. The primary energy requirements by fuel source over the modeling period are shown in Figure 7. Specifically, Table 13 shows the percentage share of total energy consumption demand per fuel. Total renewable share in energy consumption amounts 20,3% in 2020 and 22,7% in 2030 in the framework of Target 2020 Scenario. In renewable energy resources category only the small-scale hydropower projects are included and not the large hydro.

Figure 4: Capacity projection in Electricity sector (in MW)

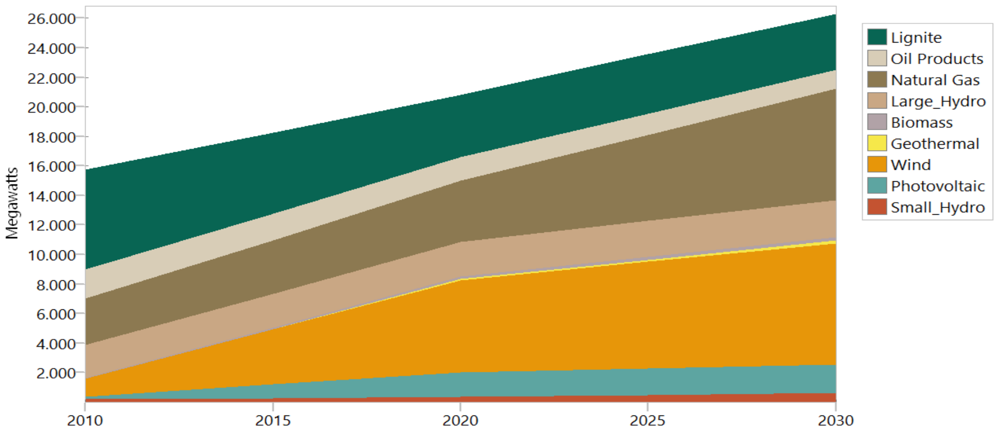

Table 11: Capacity projection in Electricity sector (in MW)

	2010	**2015**	**2020**	**2025**	**2030**
Lignite	6716	5474	4232	4006.5	3781
Oil Products	2016	1808	1600	1452	1304
Natural Gas	3123	3616.5	4110	5822.5	7535
Large_Hydro	2237	2305	2373	2441	2509
Biomass	43	107.3	171.5	194.6	217.6
Geothermal	0	24	79.3	134.7	190
Wind	1230.9	3719.7	6208.5	7208.3	8208
Photovoltaic	158.5	926.9	1695.2	1800.6	1906
Small_Hydro	205	277.6	350.2	495.2	640.2
Total	15729.4	18259	20819.7	23555.4	26290.8

Table 12: RES share in electricity generation

	2010	2015	2020	2025	2030
RES share of electricity production (MW)	1637.4	5055.5	8504.7	9833.4	11161.8
% RES share of electricity production	10.4%	27.7%	**40.8%**	41.7%	42.4%

Figure 5: Households Energy Consumption per fuel

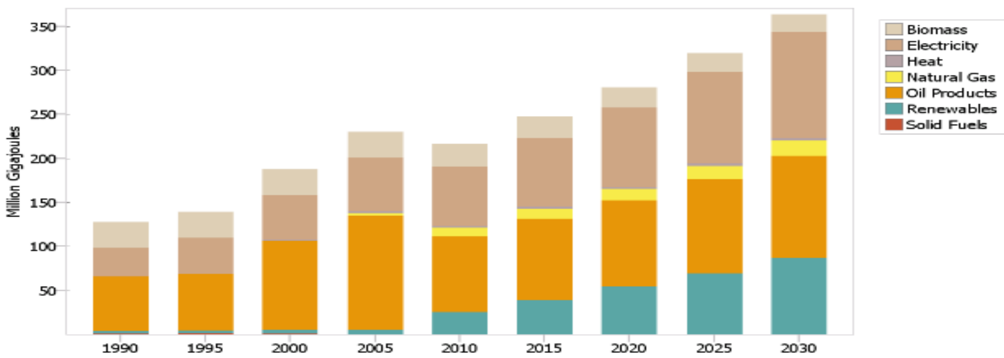

Figure 6: Transport Energy Consumption per fuel

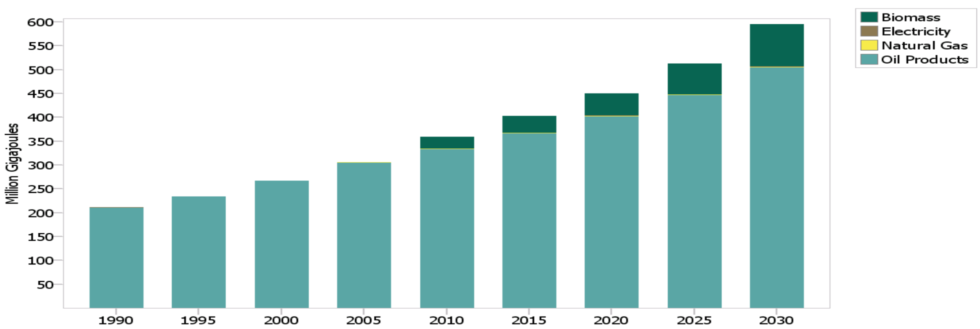

Figure 7: Total Energy Consumption per fuel

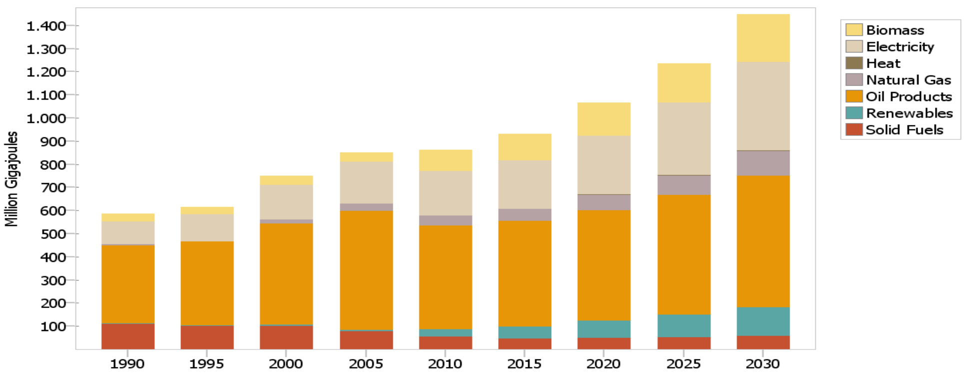

Table 13: Total Energy Consumption share per fuel (%)

	2010	2015	2020	2025	2030
Biomass	10.7	12.3	13.5	13.8	14.2
Electricity	22.1	22.3	23.9	25.2	26.5
Heat	0.2	0.2	0.2	0.2	0.2
Natural Gas	5.1	5.5	6.2	6.7	7.2
Oil Products	51.8	49.1	44.8	42	39.4
Other Renewable	3.9	5.5	6.8	7.7	8.5
Solid Fuels	6.3	5	4.7	4.3	3.9
Total Renewable	14.6	17.8	**20.3**	21.5	22.7

4.3 Target 2030 scenario

In Target 2030 scenario we follow the target set by the European Commission to increase the share of renewable energy penetration by at least 27% in 2030. This will be achieved by the introduction of RES in industry. Following Heaps et al. (2009) concerning the industry sector scenario generation, CO_2 emissions can be further reduced through the increased use of natural gas, biomass and higher participation of RES in electricity, iron and steel, cement and chemicals production sectors and in other industrial subsectors. Finally, we assume a 100% increase of Renewable Energy Sources capacity, which corresponds to 10.216 MW. Specifically, as mentioned above relying on the Hellenic Transmission System Operator S.A. we assume that till 2030 100% of the non binding offers will be achieved. Figure 8 and table 14 depict the energy consumption per fuel in the industry sector. Figure 9 depicts the total energy consumption requirements per fuel. As can be seen in Table 15, the total renewable share in 2030 amounts to 29%.

Figure 8: Industry's Energy Consumption per fuel

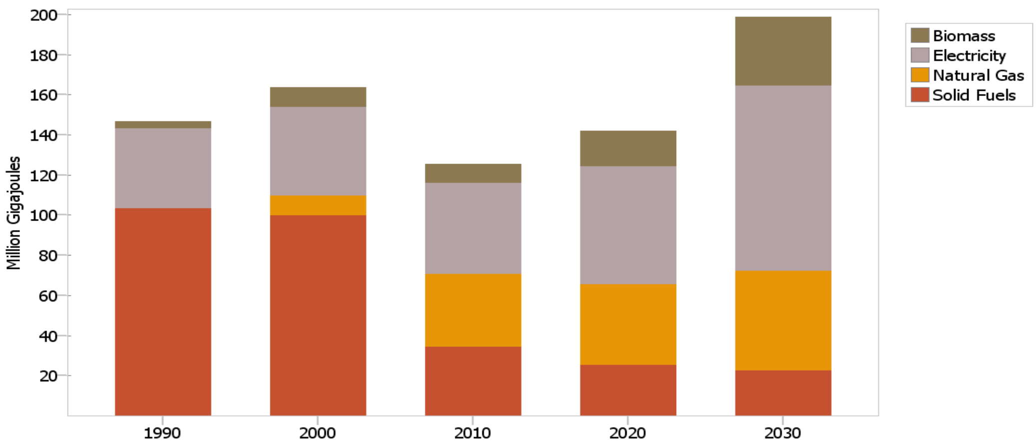

Table 14: Industry's Energy Consumption share per fuel

	1990	2000	2010	2020	2030
Biomass	2.4	6	7.6	12.4	17.2
Electricity	27.1	27	36.2	41	43.4
Natural Gas	0	6.1	28.3	28.8	31
Solid Fuels	70.4	60.9	27.9	17.7	8.3

Figure 9: Energy Consumption per fuel

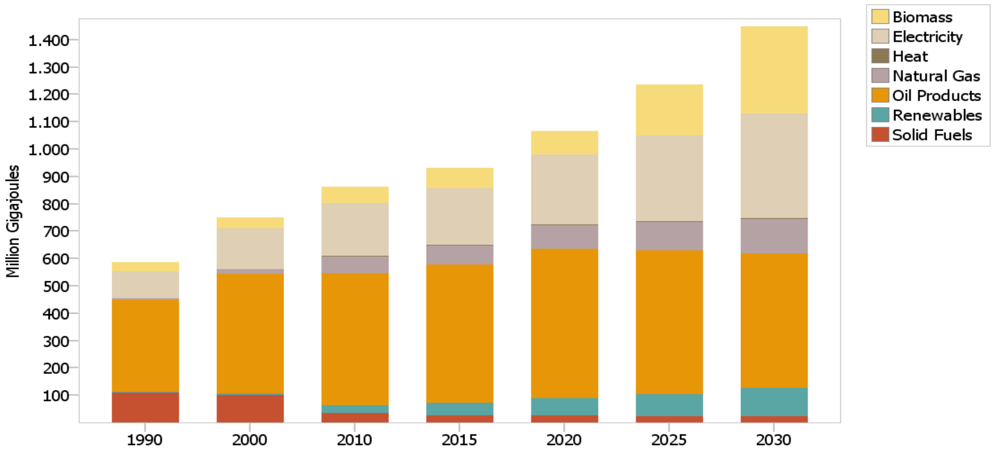

Table 15: Energy Consumption share per fuel

	2010	2015	2020	2025	2030
Biomass	10.7	12.3	13.5	15.2	21.9
Electricity	22.1	22.3	23.9	25.3	26.5
Heat	0.2	0.2	0.2	0.2	0.2
Natural Gas	5.1	5.5	6.2	8.5	8.7
Oil Products	51.8	49.1	44.8	42.4	33.9
Other Renewable	3.9	5.5	6.8	6.6	7.1
Solid Fuels	6.3	5	4.7	1.9	1.6
Total Renewable	14.6	17.8	20.3	21.8	**29**

4.4 Environment

LEAP allows each technology within the demand (Households, Agriculture and Fishing, Services, Industry, Transport and Non-Energy Fuel Use) and supply (PPC, Energy) by the various sectors to be directly linked to emission factors in the Technology and Environmental Database (hereafter TED). Thus, the model calculates the resulting emissions from energy demand based on emission factors and other technical characteristics taken from TED. The Greek power system has been always considered as particularly polluting because of the large quantities of CO_2 emitted by lignite plants.

As it is shown in Figure 10 in the framework of the Baseline scenario CO_2 emissions are projected to grow from 39.7 $MtCO_2$ to 46.7 $MtCO_2$ by 2020 and to 59.6 $MtCO_2$ by 2030 (see Table 16).[17] Observing the cumulative emissions we notice that the Target 2030 is more favourable in environmental terms than Target 2020 and Baseline scenarios. The CO_2 emitted by the energy demand system will increase compared to 1990 levels. However, carbon intensity in the electricity generation sector in Greece, as shown in Figure 11 and Table 17, will diminish by 2030 compared to 1990 levels if the policy makers follow the Target 2030 scenario.

Figure 10: Carbon intensity of Greek energy demand per scenario

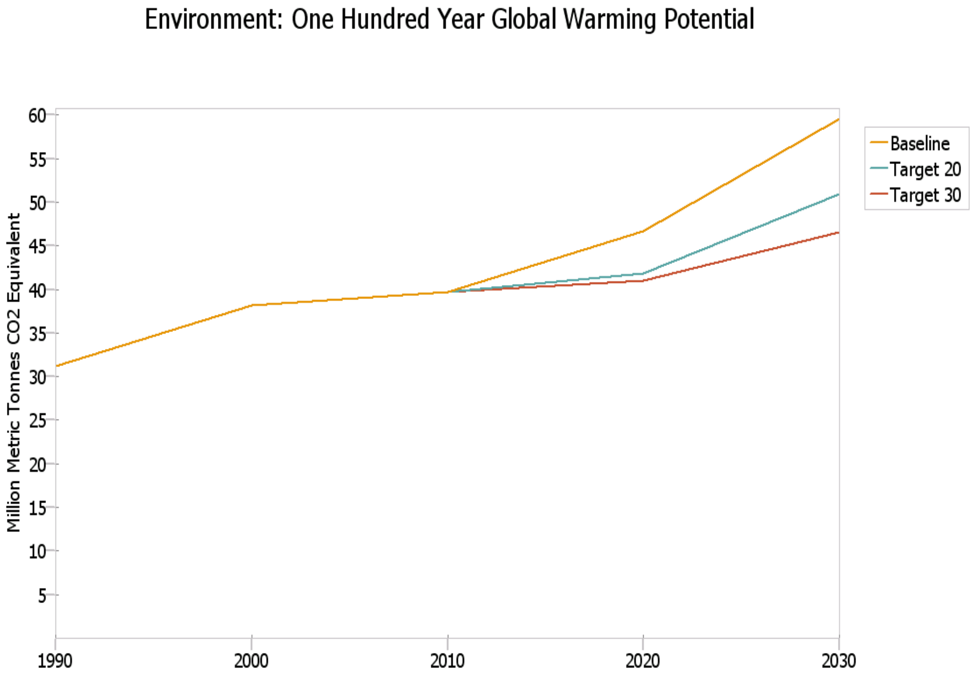

Table 16: Emissions ($MtCO_2e$) per scenario in 2020 and 2030[18]

	2010	2015	2020	2025	2030
Baseline	39.7	41.9	**46.7**	52.5	**59.6**
Target 2020	39.7	38.5	**41.9**	46	**51**
Target 2030	39.7	37.9	**41**	43.6	**46.6**

[17] Global Warming Potential (**GWP**) is an index measuring different GHGs emissions with different lifetimes and different radiative properties. CO_2 has a GWP equal to 1 for comparison reasons, CH_4 and N_2O have GWPs equal to 25 and 298 respectively (Halkos, 2010).

[18] Carbon dioxide equivalent (**CO_2e**) refers to a common unit of different GHGs showing the amount of CO_2 resulting to equivalent global warming effect.

Figure 11: Carbon intensity in Greek electricity generation sector per scenario

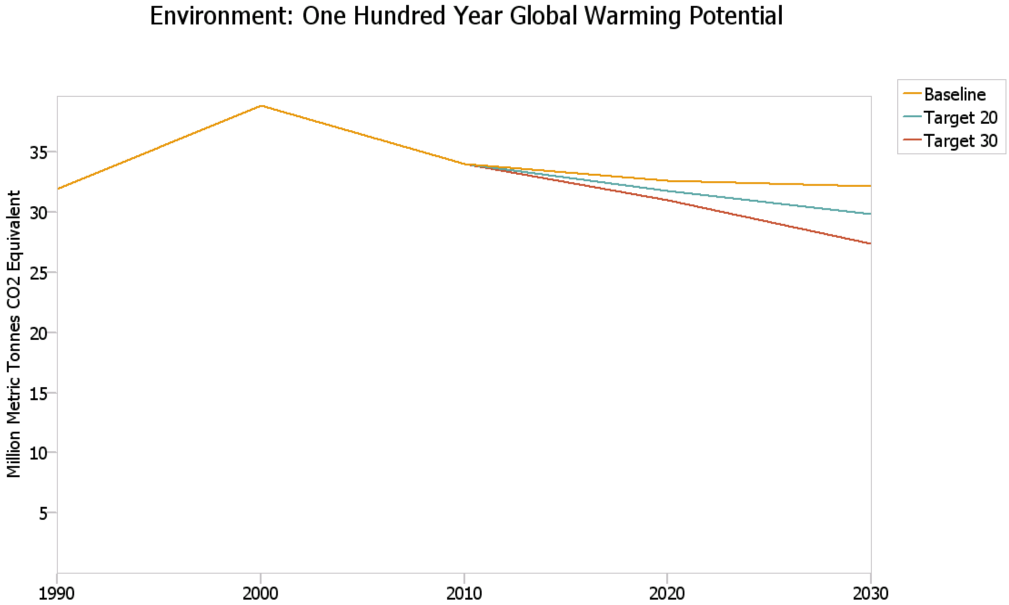

Table 17: Emissions ($MtCO_2e$) per scenario in 2020 and 2030

	1990	2000	2010	2020	2030
Baseline	32	38.9	34	32.7	32.2
Target 2020	32	38.9	34	31.8	29.9
Target 2030	32	38.9	34	31	27.4

4.5 Costs

The types of costs considered are capital costs and operating and maintenance costs as shown in Table 18. Obviously, the capital cost is the main driver of the annualized electricity generation cost. As expected, Target 2030 is the most expensive throughout the projection period as it necessitates more innovative and decisive changes. It also assumes large investments in clean energy forms. The second most expensive scenario is the Target 2020 scenario throughout the projection period.

As it is clearly observed in Figure 12 the low cost scenario is the Baseline as it does not require large changes. Specifically, the total cost of Baseline scenario amounts to €1.4 bn in 2020 and €2.2 bn in 2030. The total cost of Target 2020 amounts to €1.8 bn in 2020 and €2.9 bn in 2020 respectively. Finally, Target 2030 costs €2 bn in 2020 and €3.4 bn in 2030 respectively.[19]

[19] Part of the data used for costs (capital cost and fixed cost) and operating characteristics (efficiency, availability, etc.) are extracted from IPA Energy and Water Economics (2010).

Figure 12: Total costs per scenario in 2020 and 2030

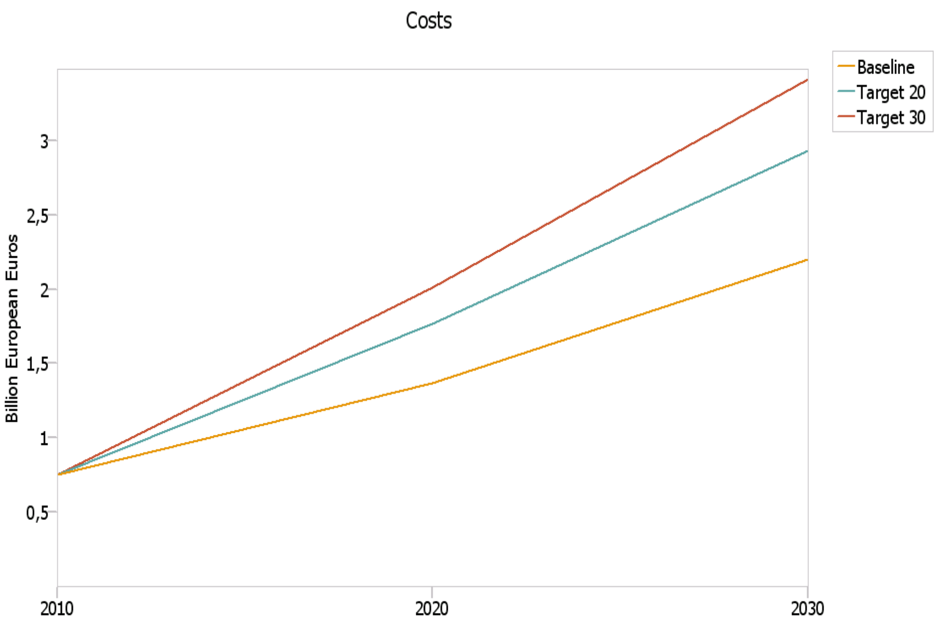

Table 18: Capital costs, fixed Operating and Maintenance (O&M) costs per scenario in 2020 and 2030 (in billion €)

	2020		
	Baseline	**Target 2020**	**Target 2030**
Capital costs	0.7	0.9	1.1
Fixed O&M costs	0.7	0.8	0.9
Total cost	**1.4**	**1.8**	**2**
	2030		
	Baseline	**Target 2020**	**Target 2030**
Capital costs	1.3	1.8	2.2
Fixed O&M costs	0.9	1.1	1.2
Total cost	**2.2**	**2.9**	**3.4**

5. Concluding Remarks

The increasing trend in energy demand worldwide, combined with the predicted exhaustion of the energy reserves of the planet in conventional energy sources and the associated environmental problems caused, lead to the necessity of increasing use of RES. Most countries worldwide and mainly the developed ones are investing heavily in infrastructure, development and production of energy, from clean sources such as the wind and the sun. The European Union sets and updates the goals, forwards EU directives and at the same time supervises the progress of each country-member on the evolution and future directions in the use of RES.

The aim of this research was to provide a look to the 2030 horizon on the energy and power system in Greece. From an environmental perspective, the Target 2030 scenario is the most favorable as it offers the highest decrease in CO_2 emissions but at the highest cost. Target 2030 is the most expensive throughout the projection period as it necessitates more innovative and decisive changes. Although the Baseline scenario is the most emissive scenario, from an economic point of view is the most favourable. Nonetheless, all the scenarios include a considerable increase in RES installed capacity. According to Law L3851/2010, the protection of the climate or the reduction of GHG emissions through the promotion of electrical energy production from RES, is a crucial element of the energy sector of the country. The further specific targets include RES electricity share (40%), RES heating and cooling share (20%), and RES transport share (10%) in order to achieve the national target of 20% contribution of the energy produced from RES to the gross final energy consumption. Additionally, the European Commission has set a target to increase the share of renewable energy penetration at least 27% by 2030.

The dominant role of lignite in electricity generation has to be reversed. The reduction of the obsolete lignite stations of the Greek energy system will provide environmental benefits. The redeployment of lignite stations from the power sector, in the long run, will contribute to climate change mitigation. The scenarios that occurred assume a substantial shift in the electricity generation mix by 2030, which is anticipated to pose several challenges. Taking into account the economic recession and the diminished investments on positive environmental solutions and policies it is of crucial importance to attract private capital and promote partnership that motivates the utilization of large scale RES. The RES integration consequently will have positive effects on the reduction of unemployment and the mobilization of economic activity. Thus securing a clean energy future for Greece will contribute to create positive perspectives on the economy and the environment as well.

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Development and evaluation of Mitigation/Adaptation policy portfolios in countries with emerging economies PROMITHEAS – 4 project results.

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Περίληψη

PROMITHEAS – 4 was an EU – FP7 project with 3 years duration (2011-13). The aim of the projecτ was to support countries with emerging economies[20] to develop and implement effective adaptation / mitigation policy portfolios with regard to post-Kyoto era. It was based on the following four pillars, i) Intensive knowledge transfer, ii) Development of a reliable data bases for all beneficiary countries, iii) Development and evaluation of Climate change Mitigation/Adaptation policy portfolios, iii) Intensive and structured policy dialogue with policy makers and market stakeholders at national and regional level and iv) Dialogue with international partners. The project combined an intensive knowledge transfer and capacity building with a comprehensive policy dialog with the beneficiary governments, mainly through the Black Sea Economic Organization (BSEC). Policy portfolios for each country were based on an initial mapping of their climate change policies. Taking into account the international standards and requests, the best suited to their capacities choices were made concerning the model (LEAP)[21], facilitating the implementation of the three scenarios[22] developed, reflecting their Climate Change policies and perspectives. In addition, the Multi criteria evaluation method AMS was used and a "tailor made" policy tool (MADAT)[23] was developed. PROMITHEAS – 4 concluded with twelve national reports. A synthesis of the most important outcomes concerning their GHG emissions, RES and Energy Efficiency trends and perspectives are synoptical presented. Most of the countries will face difficulties to participate actively in a post 2015 (COP21 Paris) international legal instrument, unless additional efforts and resources will be allocated to them to increase their knowledge and evidence base. It is worth mentioning that there is an almost complete lack of Adaptation Policies among the countries of our region. Concluding, the EU FP7 incentive to launch PROMITHEAS - 4 in the region has had a positive impact in the efforts to increase the awareness on the Climate Change Mitigation/Adaptation policy issues. It contributed to the knowledge transfer and capacity building process and has developed a useful evidence base for further incentives that are necessary to be undertaken, by policy makers and market stakeholders, in the context of the emerging Framework for Various Approaches (FVA), the New Market Mechanisms (NMM), the National Appropriate Mitigation Actions (NAMA) and the recognized needs by the countries of the region to converge with the EU policies towards 2030.

Keywords: Climate change; mitigation; adaptation; FVA; NAMA.

[20] Albania, Armenia, Azerbaijan, Bulgaria, Estonia, Kazakhstan, Moldova, Romania, Russian Federation, Serbia, Turkey and Ukraine
[21] LEAP: Long-range Energy Alternatitves Planning model
[22] Business As Usual-BAU, Optimistic-OPT, Pessimistic-PES
[23] MADAT: Mitigation/ Adaptation Development and Assessment Tool

PROMITHEAS – 4, χαράσσοντας πράσινα μονοπάτια

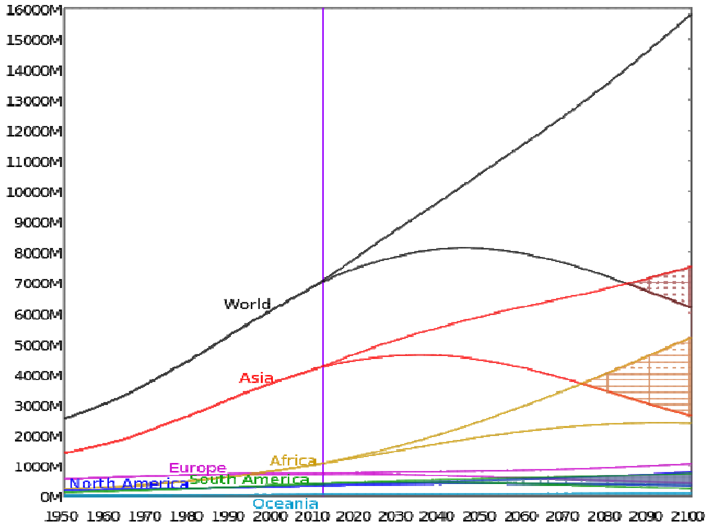
Η υπέρτατη πρόκληση

Το πρόγραμμα PROMITHEAS – 4 χρηματοδοτήθηκε από το 7^{ο} Πλαίσιο Πρόγραμμα της Ευρωπαϊκής Ένωσης. Με χρηματοδότηση περίπου 1.000.000€ και 16 εταίρους από 14 χώρες, πραγματοποιήθηκε μέσα σε τρία χρόνια (2011 – 2013).

Οι επωφελούμενες από το πρόγραμμα χώρες είχαν χαρακτηριστικά αναπτυσσόμενων οικονομιών και προέρχονταν από την περιοχή της Μαύρης Θάλασσας (10), την Εσθονία και το Καζακστάν.

Το έργο αυτό εντάσσεται στις προσπάθειες αντιμετώπισης της Κλιματικής Αλλαγής.

Όπως φαίνεται από το παρακάτω γράφημα, ο παγκόσμιος πληθυσμός προβλέπεται να αυξηθεί δραματικά τα επόμενα χρόνια και κατά συνέπεια, και η ζήτηση πρωτογενούς ενέργειας. Μια τέτοια αύξηση της ζήτησης σε ενέργεια των εκπομπών του θερμοκηπίου, προκαλεί άνοδο της θερμοκρασίας του πλανήτη.



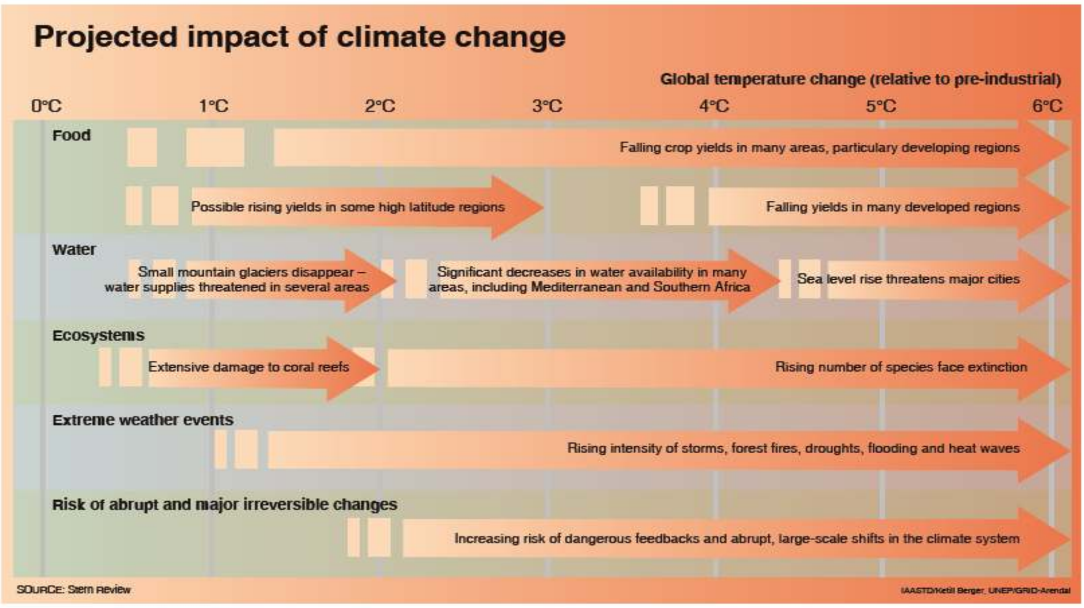
Εικόνα 1: Παγκόσμιος Πληθυσμός (1950 – 2100)[24]

Αν και οι ως τώρα συζητήσεις εστιάζουν στο πώς θα αποφευχθεί η άνοδο της θερμοκρασίας κατά 2 βαθμούς Κελσίου, το Παγκόσμιο Οικονομικό Φόρουμ προβλέπει ότι στην πραγματικότητα, μέχρι το 2060, η θερμοκρασία του πλανήτη αναμένεται να αυξηθεί μέχρι και 6 βαθμούς Κελσίου.

Τέτοιες αλλαγές στην θερμοκρασία θα επιφέρουν σταθερές και αμετάκλητες αλλαγές στον υδροφόρο ορίζοντα, στις καλλιέργειες, στα οικοσυστήματα και στα καιρικά φαινόμενα παγκοσμίως. Η αύξηση μέχρι 2^{ο} C αναμένεται ότι θα αρχίσει να επηρεάζει τις καλλιέργειες σιτηρών, μικροί παγετώνες θα αρχίσουν να λιώνουν, αυξάνοντας την στάθμη της θάλασσας, οι κοραλιογενείς περιοχές θα αντιμετωπίσουν προβλήματα και θα γίνει

[24] http://esa.un.org/unpd/wpp/unpp/panel_population.htm

εμφάνιση εξαιρετικά δεινών καιρικών φαινομένων. Για αύξηση της θερμοκρασίας κατά 6° C, υπολογίζεται ότι ο πλανήτης θα έχει να αντιμετωπίσει ξηρασία και την μείωση παραγωγής σιτηρών, την κάλυψη ξηράς από θαλάσσια ύδατα, αύξηση των υπό εξαφάνιση ειδών, λιμούς και ασθένειες στις πόλεις, καταιγίδες, πλημμύρες και καύσωνες.



Εικόνα 2: Ξεπερνώντας το όριο των 2° C

Προκειμένου να αποφευχθούν οι παραπάνω προβλέψεις, η πρόκληση της Κλιματικής Αλλαγής μπορεί να αντιμετωπισθεί μόνο με μια πράσινη, βιώσιμη και δίκαιη οικονομική ανάπτυξη.

Αυτή η ανάπτυξη οφείλει να λάβει υπόψη της την αντιμετώπισης της Κλιματικής Αλλαγής, εστιάζοντας τόσο στην μείωση των εκπομπών (με στόχο την μη υπέρβαση του σημείου των 2° C, όσο και την προσαρμογή στις αρνητικές επιπτώσεις της αλλαγής του Κλίματος (Μείωση/ Προσαρμογή).

Επιπλέον, για να είναι βιώσιμη θα πρέπει να κάνει ορθολογική διαχείριση του περιβάλλοντος και των διαθέσιμων φυσικών πόρων, προσφέροντας ταυτόχρονα μια δίκαιη συμμετοχή στην οικονομική ανάπτυξη.

Συμμετέχοντας στην προσπάθεια

Το έργο PROMITHEAS – 4, βασίστηκε σε τρεις πυλώνες.

Την μεταφορά τεχνογνωσίας σε θέματα ανάπτυξης πολιτικών μιγμάτων Μείωσης και Προσαρμογής σε νέους επιστήμονες χωρών με αναπτυσσόμενες οικονομίες – στην περίπτωση του έργου αυτού, σε 12 επωφελούμενες χώρες, καθώς επίσης και την δημιουργία δικτύου επικοινωνίας και συνεργασίας μεταξύ επιστημόνων από τις χώρες αυτές.

Την χαρτογράφηση της περιοχής που πραγματοποιήθηκε το έργο, με σκοπό να δημιουργήσει βάσεις δεδομένων και εκθέσεις μιγμάτων πολιτικής Μείωσης/ Προσαρμογής που θα μπορέσουν να χρησιμοποιηθούν σε μελλοντικά έργα. Ταυτόχρονα, η καταγραφή επιστημονικών κενών και αναγκών θα βοηθούσε την επίλυση προβλημάτων που παρουσιάζονται στην περιοχή και ευθύνονται για τις δυσκολίες δημιουργίας πολιτικών ή εφαρμογής τους.

Τέλος, δόθηκε ιδιαίτερο ενδιαφέρον στην ενημέρωση των Κυβερνήσεων των χωρών που συμμετείχαν στο πρόγραμμα, την ενημέρωση της Διεθνούς κοινότητας (ΟΗΕ) αλλά και της ενημέρωσης των παικτών της αγοράς (τράπεζες, ΜΜΕ, βιομηχανίες), με σκοπό να ξεκινήσει ένας πολιτικός διάλογος που θα διαμόρφωνε ρεαλιστικές πολιτικές, σε μια προσπάθεια επίτευξης του βέλτιστου μίγματος αυτών.

Αναπτύσσοντας μίγματα πολιτικών Μείωσης/ Προσαρμογής

Οι επωφελούμενοι εταίροι του έργου ανέπτυξαν μίγματα πολιτικών Μείωσης/ Προσαρμογής για τις χώρες τους, βασιζόμενοι σε έναν εντατικό κύκλο εκπαίδευσης και μεταφοράς τεχνογνωσίας. Το κάθε ίδρυμα συνέταξε μια εθνική έκθεση όπου ανέφερε την διαδικασία ανάπτυξης των μιγμάτων, καθώς επίσης και τις δυσκολίες ή τα προβλήματα που αντιμετώπισε.

Η κοινή μεθοδολογία που ακολούθησαν οι δώδεκα επωφελούμενοι εταίροι απαρτίζεται από έξι αλληλοεξαρτώμενα στάδια:

1. Συλλογή και επαλήθευση δεδομένων. Οι ομάδες των νέων επιστημόνων εκπαιδεύτηκαν στην δημιουργία βάσεων δεδομένων βασικών κατηγοριών (δημογραφικά, οικονομικά, κλιματικά και ενεργειακά) από επίσημες εθνικές κατά προτεραιότητα ή διεθνείς πηγές, ώστε να εξασφαλίσουν την μεγαλύτερη δυνατή αξιοπιστία των δεδομένων τους.

2. Ανάπτυξη σεναρίων. Οι ομάδες των εταίρων ακολούθησαν κοινές οδηγίες για την ανάπτυξη των τριών σεναρίων για τις χώρες τους, λαμβάνοντας υπόψη τις εθνικές υποχρεώσεις στις οποίες έχει δεσμευθεί η χώρα τους και τα πολιτικά εργαλεία που εφαρμόζονται σε αυτές (έως και 31.12.10) ή που έχουν προγραμματισθεί ή προταθεί να εφαρμοσθούν (από την 1.1.11). Τα σενάρια που αναπτύχθηκαν ήταν Business As Usual (BAU), Optimistic (OPT), Pessimistic (PES).

3. Έχοντας λάβει υπόψη τις ανάγκες και τα κενά δεδομένων που υπήρχαν στις χώρες αυτές, η επιστημονική επιτροπή του έργου βασίστηκε στην έκθεση των εταίρων που είχαν αναλάβει να αναδείξουν το βέλτιστο ενεργειακό μοντέλο και επέλεξε το Long – range Energy Alternatives Planning (LEAP) system.

Αφού εκπαιδεύτηκαν στην χρήση του, οι εταίροι συνέδεσαν τις εθνικές βάσεις δεδομένων στο λογισμικό του μοντέλου, δόμησαν το μοντέλο και τις παραμέτρους αντίστοιχα με τις περιγραφές και τα χαρακτηριστικά που περιγράφονταν στα σενάρια, διόρθωσαν και ρύθμισαν τυχόν παραλείψεις κυρίως στις Βάσεις Δεδομένων και έλαβαν τα σχετικά αποτελέσματα για τρία σενάρια.

4. Τα αποτελέσματα αυτά χρησιμοποιήθηκαν για να διαμορφωθούν τα μίγματα πολιτικών, από τα σενάρια που χρησιμοποιήθηκαν (BAU, OPT, PES).

5. Τα μίγματα αυτά, σε συνδυασμό με επικαιροποιημένη βιβλιογραφία, αξιολογήθηκαν από την πολυ-κριτηριακή μέθοδο αξιολόγησης AMS, βαθμολογούμενα με τρία κριτήρια:

τις περιβαλλοντικές τους επιδόσεις, την πολιτικής του αποδοχή και την σκοπιμότητα της εφαρμογής τους, αναδεικνύοντας έτσι το βέλτιστο μίγμα πολιτικής Μείωσης/ Προσαρμογής

6. Λαμβάνοντας υπόψη τους εθνικούς στόχους της κάθε χώρας, τα δεδομένα της και την αξιολόγηση των τριών μιγμάτων, οι εταίροι κατέληξαν στα μίγματα πολιτικών κλιματικής αλλαγής, ως προς την Μείωση.

Πολιτικός διάλογος

Όπως προαναφέρθηκε, στο έργο PROMITHEAS – 4 η ενημέρωση των κυβερνήσεων, των οργάνων λήψης αποφάσεων, των παικτών της αγοράς αλλά και της διεθνούς κοινότητας αποτέλεσε σημαντική προτεραιότητα. Για την επίτευξη των στόχων αυτών, πραγματοποιήθηκαν τα παρακάτω:

- Συνεχής Ενημέρωση των κυβερνήσεων των δώδεκα επωφελούμενων χωρών με αποστολή εκθέσεων σε ηλεκτρονική και εκτυπωμένη μορφή
- Συνεχής ενημέρωση της επιτροπή Οικονομικών και Κοινωνικών Σχέσεων του ΟΗΕ
- Παρουσίαση ενδιάμεσων αποτελεσμάτων σε συνεργασία με την PERMIS - BSEC:
    - Τρεις (3) διυπουργικές συναντήσεις
    - συνεδριάσεις ομάδων εργασίας των χωρών του BSEC
    - Μία (1) συνεδρίαση της Διακοινοβουλευτικής επιτροπής του BSEC
    - Δύο (2) διεθνή συνέδρια
- Δώδεκα (12) εθνικά συνέδρια παρουσίασης και σχολιασμού τελικών εκθέσεων με συμμετοχή υπουργείων και εκπροσώπων της αγοράς
- Ένα (1) διεθνές συνέδριο παρουσίασης τελικών εκθέσεων και συμπερασμάτων

Μεταφορά τεχνογνωσίας

Η μεταφορά τεχνογνωσίας για την πραγματοποίηση του έργου ήταν ζωτικής σημασίας παράγων. Οι εταίροι εκπαιδεύτηκαν με εξαιρετικά εντατικό ρυθμό, ώστε να είναι σε θέση να μπορούν να αναπτύξουν και να υποστηρίξουν εθνικές εκθέσεις μιγμάτων πολιτικής χωρίς την ανάγκη χρήσης ξένων φορέων, χρησιμοποιώντας επίσημες εθνικές πηγές και στηρίζοντας με σωστή τεκμηρίωση τα συμπεράσματα αλλά και τις ανάγκες που εντόπισαν.

Για την εκπαίδευσή τους, αρχικά είχε προγραμματισθεί μια εξάμηνη περίοδος μαθημάτων σε ηλεκτρονική πλατφόρμα (e – class) όπου από τους 110 συμμετέχοντες, οι 25 μόνο πέρασαν επιτυχώς τις εξετάσεις και κλήθηκαν να παρακολουθήσουν στην Αθήνα το Σεμινάριο Μελέτης Εθνικών Περιπτώσεων. Κατά την διάρκεια αυτού, τους ζητήθηκε να ολοκληρώσουν σε μια εβδομάδα μια βασική έκθεση μιγμάτων πολιτικής, βασιζόμενοι στα έξι βήματα της προαναφερθείσας μεθοδολογίας, που είχαν ήδη διδαχθεί κατά τους έξι μήνες χρήσης της ηλεκτρονικής πλατφόρμας.

Παρόλη την διάθεση υλικού, λογισμικών, βιβλιογραφίας και παραδειγμάτων, χρειάστηκε να οργανωθούν επιπλέον τρεις εντατικές εκπαιδεύσεις, με στοχευόμενες θεματικές αναλόγως των αναγκών, για να μπορέσουν να ολοκληρώσουν τις εθνικές τους εκθέσεις – προτάσεις μιγμάτων πολιτικής Μείωσης/ Προσαρμογής, που αποτελούσαν και παραδοτέα του έργου.

Εκτός από τους οργανωμένους κύκλους εκπαίδευσης, δημιουργήθηκε για τις ανάγκες των νέων επιστημόνων των εθνικών ομάδων ένα δίκτυο, όπου μπορούσαν να αλληλοενημερώνονται, να υποστηρίζονται μεταξύ τους αλλά κυρίως, να έχουν διαρκή επαφή και βοήθεια από τον συντονιστή του έργου που είχε αναλάβει και την εκπαίδευσή τους. Για τον σκοπό αυτό χρησιμοποιήθηκε η τηλε-εκπαίδευση μέσω λογισμικών αλλά και η δημιουργία φόρουμ καθώς και αλυσιδωτή αλληλογραφία (chain mails).

Τάσεις και προοπτικές

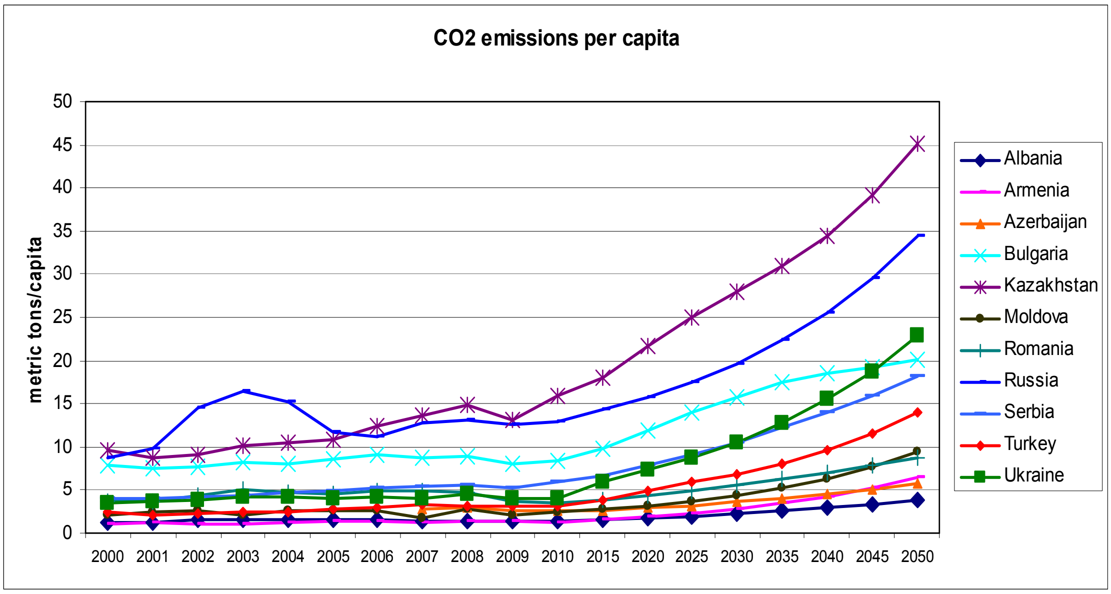
Από μια απλή παρατήρηση του πίνακα, προκύπτει οτι οι χώρες της περιοχής στερούνται πολιτικών αντιμετώπισης των προβλημάτων που σταδιακά διαμορφώνονται από την Κλιματική Αλλαγή και αυτή η κατάσταση οφείλεται στην ελλιπή πληροφόρηση για τους επερχόμενους κινδύνους. Όσο δε αφορά για την παρουσία έργων που αντιστοιχούν στους Μηχανισμούς του Κιότο, αυτή χαρακτηρίζεται ως αμελητέα, με καθαρά επιδεικτικό χαρακτήρα.

Πίνακας 1: Συμμετοχή στους μηχανισμούς Κιότο

	Ratification of Kyoto protocol	**Registered CDM projects**	**Emission trading**	**Adaptation policy**
Albania	01.04.2005	3	—	—
Armenia	25.04.2003	6	—	—
Azerbaijan	28.09.2000	5	—	√ **
Bulgaria	15.08.2002	*Annex B country*	EU-ETS,JI, GIS	√ *
Georgia	16.06.1999	6	—	—
Greece	31.05.2002	*Annex B country*	EU-ETS	√ *
Kazakhstan	19.06.2009	*Annex B country*	National ETS (2014)	—
Moldova	22.04.2003	8	—	—
Romania	19.03.2001	*Annex B country*	EU-ETS,JI,GIS	√ *
Russia	18.11.2004	*Annex B country*	JI, GIS	—
Serbia	19.10.2007	6	—	—
Turkey	28.05.2009	-	voluntary carbon market	—
Ukraine	12.04.2004	*Annex B country*	JI, GIS	—

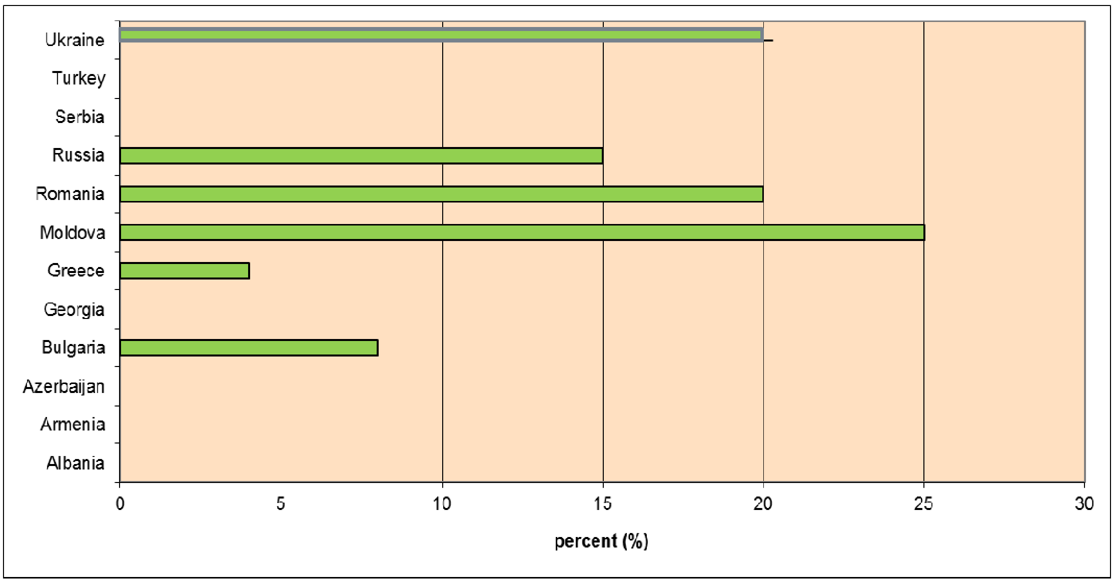
√ * Μεταφορά της οδηγίας 2007/60/ΕΚ για την αξιολόγηση και διαχείριση των κινδύνων πλημμύρας
√ ** Διαχείριση & τέλη νερού (2003, 2011)

Η εικόνα 3 δείχνει τις αναμενόμενες εκπομπές CO_2 εάν επαληθευθούν οι προβλέψεις για την οικονομική ανάπτυξη των χωρών του προγράμματος. Μια προοπτική που δεν συμβαδίζει με όποια πολιτική διακήρυξη για συμμετοχή των χωρών αυτών στις παγκόσμιες προσπάθειες αντιμετώπισης της Κλιματικής Αλλαγής.



Εικόνα 3: Εκπομπές Διοξειδίου του άνθρακα

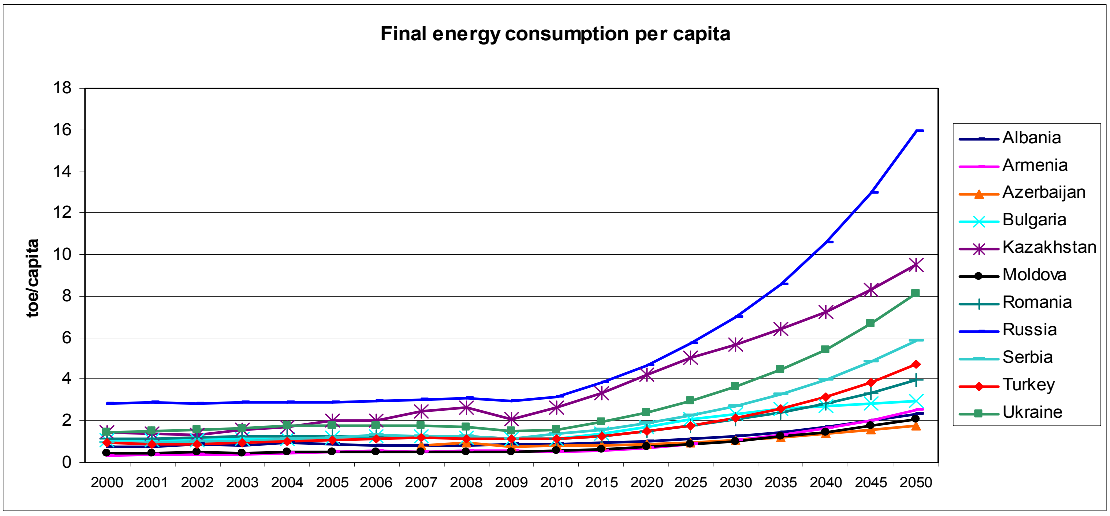
Η εικόνα 4 παρουσιάζει τους στόχους η επίτευξη των οποίων απαιτεί σημαντική ανακατανομή πόρων σε υποδομές, επενδύσεις, σε πράσινες τεχνολογίες και μεταβολές σε κοινωνικές συμπεριφορές που ακόμη δεν είναι ορατές.



Εικόνα 4: Στόχοι μείωσης εκπομπών CO_2 μέχρι το 2020

Οι χώρες που δεν εμφανίζουν στόχους μείωσης είναι αυτές που είτε δεν έχουν δεσμευθεί για μείωση των ρύπων τους, είτε δεν υπάρχουν διαθέσιμα δεδομένα που να τεκμηριώνουν την ύπαρξη εθνικών στόχων.

Στην εικόνα 5, όλες οι χώρες εμφανίζονται να διατηρούν τις συμβατικές συμπεριφορές σύνδεσης της οικονομικής τους ανάπτυξης με την ενεργειακή σπατάλη. Αν αυτή η τάση δεν καταστεί δυνατό να ανατραπεί, τότε η συνδρομή των χωρών αυτών στη μείωση των εκπομπών CO_2 θα παραμείνει περιορισμένη.



Εικόνα 5: Τελική ενεργειακή κατανάλωση (κατά κεφαλή)

Με φθίνουσα σειρά, την μεγαλύτερη ενεργειακή κατά κεφαλή κατανάλωση έχουν η Ρωσία, το Καζακστάν, η Ουκρανία και η Σερβία.

	Συσκευές	**Κτήρια***	**Τομέας Ενέργειας**	**Βιομηχανία**
Albania				
Armenia				
Azerbaijan				
Bulgaria				
Kazakhstan				
Moldova				
Romania				
Russia				
Serbia				
Turkey				
Ukraine				

Με πολιτικά εργαλεία

Χωρίς πολιτικά εργαλεία

* Διατήρηση θερμότητας, ενεργειακά πρότυπα και μόνωση, διαχείριση της ενέργειας

Συμπεράσματα

Γενικά

Σχετικά με πολιτικές των χωρών

Παρά τις πολιτικές διακηρύξεις, οι περισσότερες από τις επωφελούμενες χώρες στερούνται συνεκτικών πολιτικών μείωσης των εκπομπών CO_2 ενώ ταυτόχρονα, από όλες σχεδόν τις επωφελούμενες χώρες, απουσιάζουν πολιτικές προσαρμογής.

Η προώθηση πολιτικών ΑΠΕ γίνεται χωρίς σύνδεση με συγκροτημένες πολιτικές μείωσης εκπομπών και η εφαρμογή των μηχανισμών του Κιότο (CDM, ETS, JI) υπήρξε υποτυπώδης έως ανύπαρκτη.

Σχετικά με ανάγκες και δυναμικό

Οι χώρες της περιοχής δεν διαθέτουν το αναγκαίο ανθρώπινο δυναμικό προκειμένου να συμμετάσχουν ενεργά και να επωφεληθούν από τους υπό συγκρότηση Νέους Μηχανισμούς της Αγοράς.

Υπάρχει σημαντικό έλλειμμα ενημέρωσης στις κοινωνίες των χωρών αυτών αλλά ταυτόχρονα, υπάρχει ένα σημαντικό δυναμικό για τη μείωση της ενεργειακής έντασης (εθνικό και περιφερειακό επίπεδο).

Μείωση Ενεργειακής Έντασης

Όπως προκύπτει από την παρουσίαση των σχετικών γραφημάτων, η μείωση της ενεργειακής έντασης όχι μόνο είναι εφικτή στην περιοχή των χωρών του PROMITHEAS – 4, αλλά αποτελεί ευκαιρία για συμμετοχή στην προσπάθεια για πράσινη βιώσιμη και δίκαιη οικονομική ανάπτυξη.

Αυτό μπορεί να επιτευχθεί μεταξύ άλλων με την αύξηση των προτύπων ενεργειακής απόδοσης, την ενθάρρυνση της χρήσης πράσινων τεχνολογιών και ευφυών δικτύων, την καθιέρωση διαπραγματεύσιμων πιστοποιητικών για όλων των ειδών τις αποφυγές εκπομπών και τέλος, με την ενίσχυση εταιρειών παροχής ενέργειας με υπηρεσίες εξοικονόμησης ενέργειας.

Ανάγκες γνώσης

Η στροφή από την «καφέ» στην «πράσινη» οικονομία απαιτεί ισχυρή ενσωμάτωση γνώσης σε όλα τα επίπεδα.

Η μετεξέλιξη μιας σπάταλης, περιβαλλοντικά καταστροφικής και ρυπογόνας οικονομίας, σε μια οικονομία ορθολογικής χρήσης των φυσικώ πόρων, δημιουργίας νέων αγορών που να συνδέουν τις οικονομικές δραστηριότητες με την αντιμετώπισης της πρόκλησης της Κλιματικής Αλλαγής, απαιτούν ισχυρή παραγωγή και ενσωμάτωση γνώσης και καινοτομίας σε όλες τις παραγωγικές και κοινωνικές δραστηριότητές μας.

Το έργο PROMITHEAS – 4 ανέδειξε τις ανάγκες σε γνώσεις, τόσο στο επίπεδο των πολιτικών, όσο και στο επίπεδο της υποστήριξης των.

Για τους λήπτες αποφάσεων, θα χρειαστεί η χρήση και ανάπτυξη αξιόπιστων βάσεων δεδομένων, κάτι που απαιτεί την εκπαίδευση χρηστών στην νοοτροπία της τεκμηρίωσης της αξιοπιστίας των δεδομένων που χρησιμοποιούν.

Όπως παρατηρήθηκε κατά την διάρκεια του προγράμματος, ακόμα και υψηλόβαθμα στελέχη κυβερνήσεων και εκπαιδευτικών ιδρυμάτων έχουν ανάγκη από εκπαίδευση και διαρκή ενημέρωση σε θέματα ανάπτυξης σεναρίων, χρήσης υποθέσεων, παραμέτρων και τροποποιήσεων, αναγνώρισης του πιο ευέλικτου και αποτελεσματικού μοντέλου, της μεθόδου αξιολόγησης, και διαμόρφωσης μιγμάτων πολιτικής Μείωσης/ Προσαρμογής.

Εξαιρετικά σημαντική είναι η κάλυψη της ανάγκης για κοινωνική ευαισθητοποίηση των υπευθύνων για την χάραξη των πολιτικών της κάθε χώρας, όπως και των υπευθύνων φορέων – παικτών της αγοράς.

Τέλος, θα πρέπει να επισημανθεί οτι όσο η ενημέρωση και η ευαισθητοποίηση της κοινωνίας παραμένει ελλιπής και αναποτελεσματική, πολιτικές που διαμορφώνονται σε υψηλά επίπεδα θα συναντούν ισχυρά εμπόδια στην εφαρμογή τους, καθώς θα έρχονται αντιμέτωπες με κατεστημένες κοινωνικές συμπεριφορές του παρελθόντος. Η ανάγκη αντιμετώπισης της υπέρτατης πρόκλησης που αναφέρθηκε αρχικά, είναι πολύ πιο επείγουσα από όσο φανταζόμαστε.

Αστικό περιβάλλον και ρύπανση: ανάλυση συγκεντρώσεων αιωρούμενων σωματιδίων στη περιοχή του PM_{10} και $PM_{2.5}$

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Περίληψη
Στο άρθρο αυτό αναλύονται τα αποτελέσματα μετρήσεων που διενεργήθηκαν στην αστική περιοχή της πόλης του Βόλου, στο πλαίσιο του προγράμματος Περιβαλλοντικής Πολιτικής Life+ ACEPT-AIR. Συγκεκριμένα, στο άρθρο μελετώνται οι συγκεντρώσεις των αιωρουμένων σωματιδίων αεροδυναμικής διαμέτρου μικρότερης των 10 μm (PM_{10}) και μικρότερης της 2.5μm ($PM_{2.5}$) από τέσσερις διατάξεις δειγματοληψίας αερολύματος σε κατάλληλα φίλτρα ευρισκόμενα στο σταθμό μέτρησης της Περιφερειακής Ενότητας Μαγνησίας και Σποράδων, ο οποίος είναι εγκατεστημένος στο κέντρο της πόλης. Οι αναλύσεις που παρουσιάζονται καλύπτουν τη θερμή περίοδο του έτους 2011 (Αύγουστος) και την ψυχρή περίοδο του έτους 2012 (Φεβρουάριος). Από την ανάλυση των ληφθέντων στοιχείων προσδιορίζονται και αξιολογούνται τα επίπεδα των μέσων εποχικών της χημικής σύστασης των αιωρούμενων σωματιδίων στην πόλη του Βόλου και καταβάλλεται προσπάθεια σύγκρισης με αποτελέσματα αντίστοιχων μελετών, που έχουν παρουσιαστεί στη διεθνή βιβλιογραφία και αφορούν άλλες περιοχές.

Λέξεις Κλειδιά: *αστική ρύπανση, αιωρούμενα σωματίδια PM_{10}, $PM_{2.5}$,Βόλος.*

1. ΕΙΣΑΓΩΓΗ

Η αυξανόμενη εκβιομηχάνιση σε συνδυασμό με την ταυτόχρονη ανάπτυξη και την αύξηση της πυκνότητας των αστικών περιοχών είναι στενά συνδεδεμένες με την εμφάνιση περιβαλλοντικών προβλημάτων. Από τις αρχές της δεκαετίας του ‘80 κατέστη σαφές ότι, η ατμοσφαιρική ρύπανση επηρεάζει αρνητικά την υγεία των ανθρώπων και των ζώων, προκαλεί ζημιές στη βλάστηση, την ποιότητα του αστικού εδάφους και στα υλικά. Οι αρνητικές επιδράσεις δεν αφορούν μόνο τις μεγάλες πόλεις αλλά και τις μεσαίου μεγέθους αστικές περιοχές. Πολλοί ερευνητές έχουν μελετήσει τα προβλήματα ατμοσφαιρικής ρύπανσης στις μεσαίου μεγέθους αστικές περιοχές που χαρακτηρίζονται από υψηλή αστική πυκνότητα και έχουν εγκατεστημένες στον περιαστικό κυρίως χώρο βιομηχανικές μονάδες (Ziomas *et al.* 1989, Kelessis, 2001, Papamanolis, 2001, Triantafillou *et al.* 2002, Karandinos-Riga *et al.* 2006, Karanasiou et al. 2007b, Karanasiou et al.2009, Papanastasiou and Melas, 2009, Proias *et al.* 2009, Papaioannou *et al.* 2010).

Τα ατμοσφαιρικά αερολύματα μπορούν να χαρακτηριστούν ως πολύ «δυναμικός παράγοντας» που επηρεάζει την ανθρώπινη ζωή με πολλούς τρόπους. Οι δυσμενείς επιπτώσεις στην ανθρώπινη υγεία που προκαλούνται από τα υψηλά επίπεδα συγκέντρωσης ατμοσφαιρικών σωματιδίων βρίσκονται στο επίκεντρο του επιστημονικού ενδιαφέροντος των σχετικών ερευνών (Wallace, 2000, Nastos 2008, Nastos *et al.* 2010, Samoli *et al.* 2011).

Αναφορικά με τη σύστασή τους, τα αιωρούμενα σωματίδια αποτελούνται από μια ανόργανη φάση (στερεό ανόργανο υλικό, υδατοδιαλυτά ανόργανα άλατα, στοιχειακός άνθρακας, κ.ά.) και μια οργανική φάση (οργανικός άνθρακας). Τα μικρά σωματίδια μπορεί να περιέχουν θειικά, νιτρικά, αμμώνιο, μόλυβδο, στοιχειακό άνθρακα και οργανικές ενώσεις. Τα σωματίδια αυτά έχουν κυρίως ανθρωπογενή προέλευση, αν και ένα σημαντικό ποσοστό τους οφείλεται στις φυσικές πυρκαγιές. Αντίθετα, τα μεγάλα σωματίδια αποτελούνται κυρίως από υλικά που συναντάμε στο φλοιό της Γης (πυριτικά άλατα, οξείδια του αργιλίου, του ασβεστίου, του σιδήρου, κ.ά.) και τους ωκεανούς (νάτριο και χλώριο). Ορισμένα συστατικά, όπως τα νιτρικά ή τα ίχνη μετάλλων, βρίσκονται τόσο στα μικρά όσο και στα μεγάλα σωματίδια.

Τα αιωρούμενα σωματίδια, ως ατμοσφαιρικός ρύπος, αποτελούν ένα μείγμα στερεών και υγρών σωματιδίων που ποικίλουν σε μέγεθος, σύνθεση και προέλευση. Επειδή μόνο τα πολύ μικρά σωματίδια μπορούν με την εισπνοή να φτάσουν μέχρι τα τελικά τμήματα του αναπνευστικού δένδρου, ο όρος «εισπνεόμενα σωματίδια» εξ ορισμού περιλαμβάνει σωματίδια με αεροδυναμική διάμετρο μικρότερη των 10 μm (PM_{10}), που εναποτίθενται κυρίως στις κυψελίδες των πνευμόνων και με την πάροδο του χρόνου επιφέρουν σοβαρές βλάβες στην ανθρώπινη υγεία (Churg and Brauer 2000).

Οι επιδημιολογικές έρευνες των τελευταίων δεκαετιών δείχνουν αυξημένη νοσηρότητα και θνησιμότητα σε αστικές περιοχές λόγω υψηλών συγκεντρώσεων αιωρουμένων εισπνεόμενων σωματιδίων, ιδιαίτερα αυτών με μικρή αεροδυναμική διάμετρο PM_{10} και $PM_{2.5}$ (Seaton *et al.* 1995, Prichard *et al.* 1996, Schwartz *et al.* 1996, Costa and Dreher 1997, Pope *et al.* 2002). Συνεπώς, οι επιπτώσεις των αιωρούμενων σωματιδίων στην υγεία των ανθρώπων είναι σημαντικές και καθορίζονται τόσο από το μέγεθός τους, όσο και από τη χημική τους σύσταση. Μακροχρόνια, η εισπνοή σωματιδίων προκαλεί διάφορες μορφές πνευμονοκονιάσεων, άσθματος ή, σε ορισμένες περιπτώσεις, καρκινογένεση.

Το έργο ACEPT-AIR, εντός του πλαισίου του οποίου έγιναν οι μετρήσεις που εμφανίζονται στο άρθρο αυτό, στοχεύει: (α) στην ανάδειξη της σχετικής συμβολής των πολλαπλών ανθρωπογενών και άλλων πηγών στις παρατηρούμενες συγκεντρώσεις αερολυμάτων στον αέρα, (β) στην καταγραφή της σχετικής συμβολής των δευτερογενώς παραγόμενων σωματιδίων σε σχέση με τα παραγόμενα από πρωτογενείς πηγές, λαμβάνοντας υπόψη τις ατμοσφαιρικές συνθήκες οι οποίες συμβάλλουν στη δημιουργία πρωτογενών και δευτερογενών αιωρουμένων σωματιδίων, ανάλογα και με το χαρακτήρα κάθε τοποθεσίας.

Η πόλη του Βόλου είναι μια παράκτια πόλη μεσαίου μεγέθους στην περιοχή της Θεσσαλίας που εκτείνεται κατά μήκος του βόρειου τμήματος του Παγασητικού Κόλπου, στην ανατολική ακτή της Κεντρικής Ελλάδας. Είναι μια από τις ελληνικές πόλεις που υποφέρουν από την ατμοσφαιρική ρύπανση. Η περίπτωση του Βόλου είναι ένα ενδιαφέρον παράδειγμα, όπου κατά τις τελευταίες δεκαετίες η αστικοποίηση και η αυξημένη εκβιομηχάνιση έχουν ως αποτέλεσμα την υποβάθμιση της ποιότητας του αέρα στην περιοχή. Οι μετεωρολογικοί παράγοντες διαδραματίζουν σημαντικό ρόλο στην ανάπτυξη της ατμοσφαιρικής ρύπανσης, ενώ η σύνθετη τοπογραφία του Βόλου οξύνει επεισόδια ατμοσφαιρικής ρύπανσης.

Ο κύριος στόχος του άρθρου είναι η ανάλυση της χημικής σύστασης των αιωρούμενων σωματιδίων στην πόλη του Βόλου. Τα αποτελέσματα της ανάλυσης αφορούν τη χημική ανάλυση του κλάσματος των εισπνεύσιμων (PM_{10}) και των αναπνεύσιμων ($PM_{2.5}$) αιωρούμενων σωματιδίων στο Βόλο, σε δύο χρονικές περιόδους που καλύπτουν τη θερμή περίοδο (Αύγουστος 2011) και την ψυχρή περίοδο (Φεβρουάριος 2012) του έτους.

2. ΑΕΡΙΑ ΡΥΠΑΝΣΗ ΚΑΙ ΕΠΙΔΗΜΙΟΛΟΓΙΚΕΣ ΜΕΛΕΤΕΣ

Εκτός από το μέγεθος και τη χημική σύσταση των συγκεντρώσεων των αιωρουμένων εισπνεόμενων σωματιδίων, υπάρχουν και άλλοι παράγοντες, όπως οι μετεωρολογικές συνθήκες, ο ιστός των πόλεων, αλλά και η συνέργεια μεταξύ των ρυπογόνων χημικών ουσιών που επηρεάζουν τα επίπεδα της ατμοσφαιρικής ρύπανσης (Nastos *et al.* 2006, 2008, Larissi *et al.* 2010). Είναι ήδη γνωστό από την εποχή του Ιπποκράτη (450 π.Χ.) ότι κλιματολογικοί παράγοντες, όπως η θερμοκρασία και η σχετική υγρασία, επηρεάζουν την ανθρώπινη υγεία. Η άποψη αυτή ενισχύεται και από επιδημιολογικά στοιχεία. Χαρακτηριστικά αναφέρονται οι καύσωνες του 1976, 1995 και του 1998 στην πόλη του Λονδίνου, στους οποίους αποδόθηκε η κατά 15% αύξηση της ολικής θνησιμότητας κατά τη διάρκεια των ημερών της αυξημένης θερμοκρασίας (Seaton *et al.* 1995, Hajat *et al.* 2002) και ο καύσωνας του Ιουλίου του 1987 στην Αθήνα, που συσχετίστηκε με 2000 επιπλέον θανάτους, δηλαδή με 97% αύξηση της ημερήσιας θνησιμότητας (Katsouyanni *et al.* 1993, Panagiotakos *et al.* 2004).

Γενικότερα, από σχετικές μελέτες έχει διαπιστωθεί ότι, η αύξηση της θερμοκρασίας του ατμοσφαιρικού αέρα και η δημιουργία συνθηκών καύσωνα αποτελούν αιτία θανάτων σε πολλές χώρες και αυξάνει τη νοσηρότητα σε συχνότητα και ένταση. Ειδικότερα, στην Ελλάδα δύο κύματα καύσωνα παρατηρήθηκαν το καλοκαίρι του 2007 με συνέπεια την πρόκληση αυξημένου αριθμού κρουσμάτων νοσηρότητας σε ευαίσθητες ομάδες του πληθυσμού (Theoharatos *et al.* 2010). Τέλος, από μελέτη που έγινε σε 44 πόλεις των Η.Π.Α. έδειξε ότι η αυξημένη θνησιμότητα συνδέεται με την υψηλή μεταβλητότητα των ημερήσιων θερμοκρασιών του καλοκαιριού (McMichael and Beaglehole 2000).

Ο αέρας που αναπνέουμε περιέχει διάφορα επίπεδα ρύπων, που κυρίως προέρχονται από την καύση ορυκτών καυσίμων, όπως στα αυτοκίνητα, στη βιομηχανία και στην παραγωγή ενέργειας. Οι πιθανές επιπτώσεις της ατμοσφαιρικής ρύπανσης στη δημόσια υγεία μπορούν να εκφραστούν με διάφορους δείκτες όπως η μείωση του προσδόκιμου ζωής, ο αριθμός των πρόωρων θανάτων και ο αριθμός των εισαγωγών στα νοσοκομεία. Πολλές επιδημιολογικές μελέτες που έγιναν ως τώρα έχουν δείξει όχι μόνο μια συσχέτιση μεταξύ της ατμοσφαιρικής ρύπανσης και εξάρσεων χρόνιων πνευμονικών νόσων, αλλά και αύξηση των θανάτων από καρδιαγγειακές παθήσεις, ιδιαίτερα σε ηλικιωμένα και άτομα με υποκείμενες καρδιοπνευμονικές παθήσεις (Glantz 1993, Seaton *et al.* 1995). Κατά τη δεκαετία του '90 στην Ευρώπη, συμπεριλαμβανομένης και της Ελλάδας, έγινε προσπάθεια αποτίμησης της επίπτωσης της ατμοσφαιρικής ρύπανσης στην καρδιοαγγειακή θνησιμότητα, από την πολυκεντρική μελέτη APHEA II (Air Pollution on Health: European Approach).

Στην Ελλάδα μελετήθηκαν ημερήσια στοιχεία ρύπων, θερμοκρασίας και υγρασίας, από την περιοχή της Αθήνας και για τα έτη 1990-1997, δείχνοντας θετική σχέση μεταξύ της ατμοσφαιρικής ρύπανσης, της ολικής αλλά και της καρδιοαγγειακής θνησιμότητας

(Katsouyanni *et al.* 1997). Από τους Paliatsos *et al.* (2006) έγινε προσπάθεια προσδιορισμού των επιπτώσεων του υποβιβασμού της ποιότητας του ατμοσφαιρικού περιβάλλοντος της ευρύτερης περιοχής της Αθήνας στον αριθμό των παιδιών, ηλικίας μέχρι και 14 ετών, που εισάγονταν για νοσηλεία με κρίσεις παιδικού άσθματος, κατά τη διάρκεια της περιόδου 1984-2000. Από τη μελέτη διαπιστώθηκε ότι, οι ατμοσφαιρικοί ρύποι όπως ο καπνός, το διοξείδιο του θείου και το μονοξείδιο του άνθρακα κυρίως ευθύνονταν για τον αριθμό των εισαγόμενων παιδιών με συμπτώματα παιδικού άσθματος.

Στοιχεία των επιδημιολογικών μελετών συγκλίνουν στην ύπαρξη θετικής σχέσης μεταξύ συγκέντρωσης αιωρούμενων σωματιδίων και αναπνευστικών συμπτωμάτων (EPA 2008). Επιπλέον, η έκθεση ανθρώπων σε συγκέντρωση αιωρούμενων σωματιδίων που προέρχονται από εξατμίσεις πετρελαιοκίνητων οχημάτων, οδηγεί σε πνευμονικές φλεγμονές, οξειδωτικές αντιδράσεις και αλλεργική ευαισθητοποίηση (EPA 2008). Βάσει των προηγούμενων στοιχείων και επιδημιολογικών μελετών, προκύπτει πως οι επιπτώσεις στο καρδιαγγειακό σύστημα λόγω βραχυχρόνιας έκθεσης σε αυξημένες συγκεντρώσεις αιωρούμενων σωματιδίων συνδέονται κυρίως με καρδιακή ανεπάρκεια και ισχαιμία του μυοκαρδίου. Επειδή τα αιωρούμενα σωματίδια με διάμετρο μικρότερη των 10 μm (PM_{10}) που προέρχονται από ανθρωπογενείς δραστηριότητες και φυσικές πηγές μπορούν να προκαλέσουν δυσμενείς επιπτώσεις σε ευπαθή άτομα, όπως τα ασθματικά παιδιά, οι Nastos *et al.* (2010) μελέτησαν τις πιθανές επιδράσεις των υπαίθριων συγκεντρώσεων των PM_{10} στις εισαγωγές στα νοσοκομεία λόγω των παιδιατρικών παροξύνσεων άσθματος στην Αθήνα, κατά τη διάρκεια της περιόδου 2001-2004. Επίσης, αντίστοιχη μελέτη πραγματοποιήθηκε για τον προσδιορισμό της σχέσης μεταξύ ατμοσφαιρικής ρύπανσης και επισκέψεων στο νοσοκομείο της πόλης του Βόλου εξαιτίας αναπνευστικών και καρδιαγγειακών παθήσεων, στη διάρκεια της περιόδου 2001-2007 (Kalantzi *et al.* 2011).

Τα ευρήματα της μελέτης υποδηλώνουν μια σημαντική σχέση μεταξύ της επιβάρυνσης της νοσηρότητας από αναπνευστικές και καρδιαγγειακές παθήσεις και των επιπέδων συγκέντρωσης των ατμοσφαιρικών ρύπων. Τέλος, οι Samoli *et al.* (2011) διερεύνησαν τις βραχυπρόθεσμες επιπτώσεις των αιωρούμενων σωματιδίων με αεροδυναμική διάμετρο μικρότερη των 10μg/m^3 (PM_{10}), του διοξειδίου του θείου (SO_2), του διοξειδίου του αζώτου (NO_2) και του επιφανειακού όζοντος (O_3) για τις παιδιατρικές εισαγωγές έκτακτης ανάγκης άσθματος στην Αθήνα, κατά την περίοδο από το 2001-2004. Διερευνήθηκαν οι επιδράσεις της εποχής, του φύλου, της ηλικίας και η παρουσία της σκόνης της ερήμου που μεταφέρεται κυρίως από την περιοχή της Σαχάρας. Τα ευρήματα αυτής της μελέτης μας επιβεβαιώνουν την ευθύνη των PM_{10} σε περιστατικά εισαγωγής στα νοσοκομεία λόγω έκτακτων περιστατικών εμφάνισης παιδικού άσθματος, τα οποία εμφανίζουν έξαρση κατά τη διάρκεια ημερών με επεισόδια μεταφοράς σκόνης από την περιοχή της Σαχάρας.

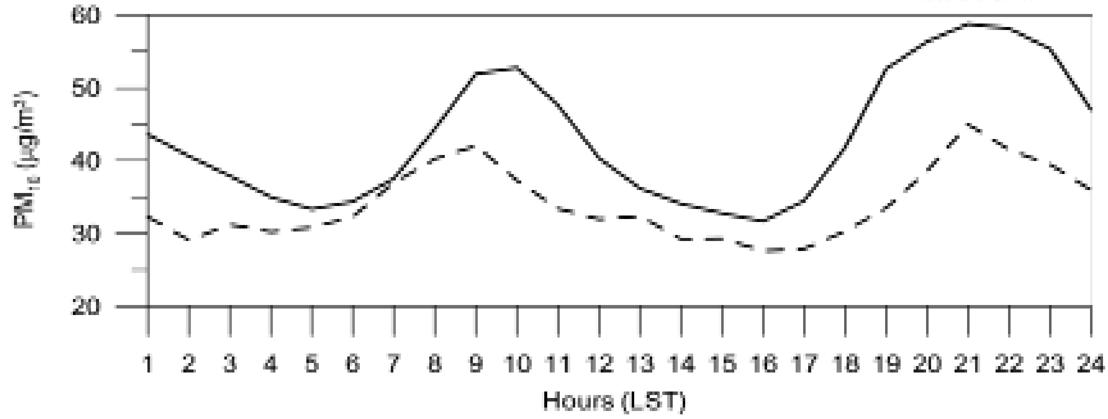
3. ΑΕΡΙΑ ΡΥΠΑΝΣΗ ΣΤΗΝ ΠΟΛΗ ΤΟΥ ΒΟΛΟΥ

Η πόλη του Βόλου βρίσκεται σε μια περιοχή με σύνθετη τοπογραφία. Σε απόσταση περίπου 3 km, βορειοανατολικά της πόλης, βρίσκονται οι πρόποδες του Πηλίου (με συνολικό υψόμετρο 1550 m), που εκτείνεται κατά μήκος της χερσονήσου της Μαγνησίας στην ανατολική ακτή. Στα βορειοδυτικά είναι περιτριγυρισμένη από λόφους των οποίων το ύψος φτάνει περίπου το 500 m. Το κλίμα του Βόλου είναι μεσογειακού τύπου με υγρούς και ήπιους χειμώνες και ζεστά, ξηρά καλοκαίρια. Γνωρίζουμε ότι το μεσογειακό κλίμα χαρακτηρίζεται από έλλειψη βροχοπτώσεων κατά τη θερμή περίοδο του έτους ενώ οι περισσότερες βροχές εμφανίζονται τον Οκτώβριο και κατά τους χειμερινούς μήνες. Η ημερήσια διάρκεια της ηλιοφάνειας εμφανίζει ελάχιστο τον Ιανουάριο και μέγιστο τον Ιούλιο.

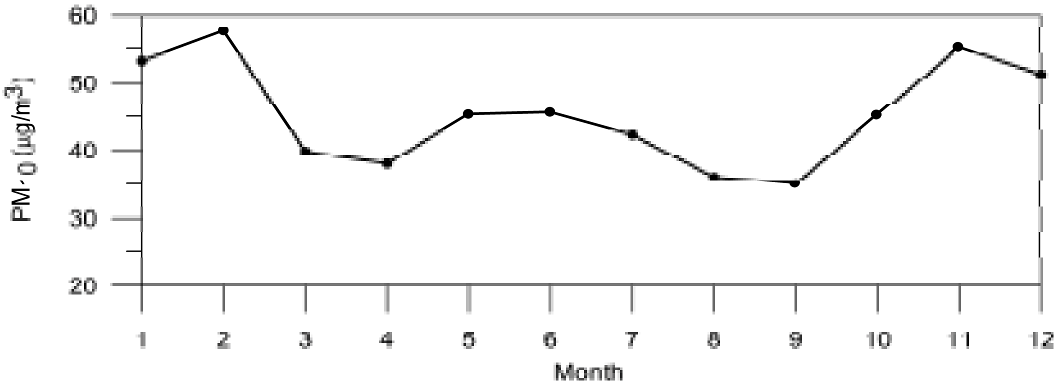
Η έντονη ηλιοφάνεια και η υψηλή θερμοκρασία, αποτελούν ιδανικές συνθήκες για την παραγωγή φωτοχημικών ρύπων. Επίσης, η παρουσία ορεινών όγκων, σε συνδυασμό με την γειτνίαση της θάλασσας, οδηγούν σε ανάπτυξη τοπικών παλινδρομικών συστημάτων κυκλοφορίας του αέρα, περίπτωση που απαντάται στα περισσότερα μεγάλα αστικά κέντρα και δυσχεραίνει σημαντικά τη δυνατότητα καθαρισμού της ατμόσφαιρας με τους μηχανισμούς διάχυσης και μεταφοράς. Σημαντικότατο ρόλο στη διαμόρφωση των επιπέδων ρύπανσης διαδραματίζει επίσης η ένταση του πνέοντος ανέμου και η εμφάνιση θερμοκρασιακών αναστροφών. Αναλυτικότερη περιγραφή των κλιματολογικών παραμέτρων της περιοχής υπάρχουν σε σχετικές εργασίες (μεταξύ άλλων Papamanolis 2001, Papanastasiou and Melas 2009, Proias *et al.* 2009a, Papaioannou *et al.* 2010).

Το πρόβλημα της ατμοσφαιρικής ρύπανσης στην περιοχή μελέτης σχετίζεται με την τοπογραφία της περιοχής και τον πολεοδομικό σχεδιασμό της πόλης του Βόλου, καθώς και με τη γεωγραφική θέση των πηγών ρύπανσης. Οι πηγές διακρίνονται σε σταθερές (λειτουργία βιομηχανικών μονάδων και συστημάτων θέρμανσης) και κινητές πηγές (κυκλοφορία και λειτουργία λιμανιού). Στην ευρύτερη περιοχή του Βόλου υπάρχουν δύο βιομηχανικές περιοχές. Η μία βρίσκεται στα δυτικά της πόλης και η άλλη σε απόσταση λίγων χιλιομέτρων στα βορειοδυτικά της πόλης. Οι βιομηχανίες του νομού που ανήκουν στους τομείς που ευθύνονται για τη ρύπανση του ατμοσφαιρικού περιβάλλοντος της περιοχής, ανέρχονται σε 347, από τις οποίες ένα ποσοστό 15% περίπου είναι εγκατεστημένο στο εσωτερικό των δύο βιομηχανικών περιοχών. Σε αυτές τις δύο περιοχές υπάρχουν βιομηχανίες όλων των κλάδων με αποτέλεσμα να συμβάλλουν στην επιδείνωση του προβλήματος της ρύπανσης της ατμόσφαιρας της περιοχής. Εκτός αυτών, μια μεγάλη βιομηχανία παραγωγής τσιμέντου βρίσκεται στην ακτή, σε μικρή απόσταση από την ανατολική πλευρά της πόλης. Επειδή η περιοχή του λιμανιού βρίσκεται δίπλα στο δυτικό άκρο της πόλης, αυτό έχει σαν συνέπεια τη συνεχή διέλευση αυτοκινήτων τουριστών τόσο προς το λιμάνι, όσο και προς το Πήλιο. Η δραστηριότητα αυτή επιδεινώνει τα κυκλοφοριακά προβλήματα της πόλης και αποτελεί ρυπογόνο πηγή (Proias *et al.* 2009).

Ιδιαίτερο ενδιαφέρον παρουσιάζει η μεταβλητότητα της μέσης ενδοημερήσιας μεταβολής των συγκεντρώσεων PM_{10} για την απεικόνιση της οποίας χρησιμοποιούμε το Σχήμα 1. Στο Σχήμα αυτό παρουσιάζεται για τη χρονική περίοδο 2001-2007 η μέση ενδοημερήσια μεταβολή των συγκεντρώσεων PM_{10} με συνεχή γραμμή κατά τη χειμερινή περίοδο και με διακεκομμένη γραμμή κατά τη θερμή περίοδο του έτους,.



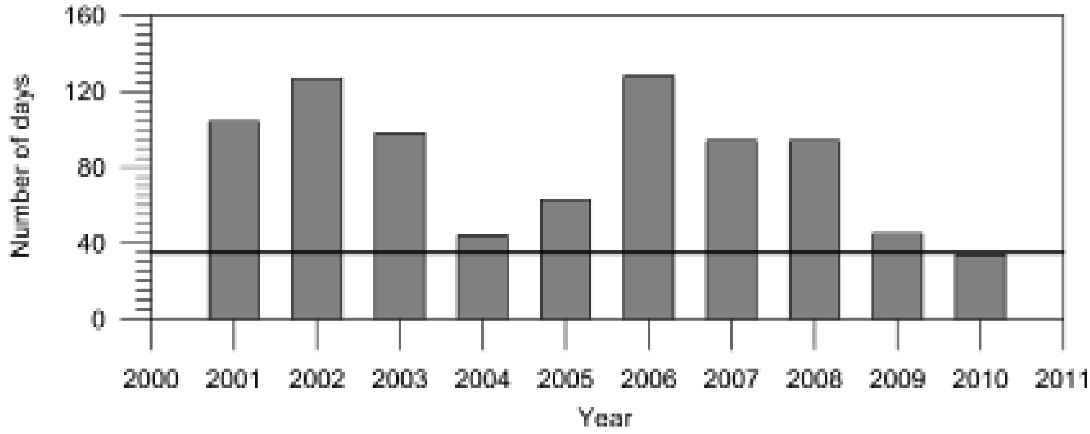
Σχήμα 1: Μέση ενδοημερήσια μεταβολή των συγκεντρώσεων των PM_{10} κατά τη χειμερινή περίοδο (συνεχής γραμμή) και τη θερμή περίοδο (διακεκομμένη γραμμή) του έτους, από 2001 ως 2007.



Σχήμα 2: Μέση ενδοετήσια μεταβολή των συγκεντρώσεων PM_{10} στην περιοχή του Βόλου από 2001 ως 2007.

Το πρόβλημα της ατμοσφαιρικής ρύπανσης στην πόλη του Βόλου έχει μελετηθεί από αρκετούς ερευνητές (Papamanolis 2001, Karandinos-Riga and Saitanis 2005, Papanastasiou and Melas 2009, Proias *et al.* 2009a, Papaioannou *et al.* 2010, Proias *et al.* 2012). Προκειμένου να αναδειχθούν κάποιες χαρακτηριστικές πτυχές του προβλήματος αυτού, παρουσιάζονται κάποια στοιχεία από μελέτες που έχουν πραγματοποιηθεί και τα αποτελέσματά τους έχουν ήδη δημοσιευτεί. Πιο συγκεκριμένα, στο Σχήμα 2 παρουσιάζεται η μέση ενδοετήσια μεταβολή των συγκεντρώσεων PM_{10} στην περιοχή του Βόλου από το 2001 ως το 2007 που παρουσιάσθηκε στην εργασία των Proias *et al.* (2009b). Οι Proias *et al.* (2011) ανέλυσαν τις μέσες ημερήσιες συγκεντρώσεις των PM_{10}, στην πόλη του Βόλου και διαπίστωσαν ότι παρατηρούνται υπερβάσεις της ημερήσιας οριακής τιμής των 50 $\mu g/m^3$ (EU 1999). Επιπλέον, στο Σχήμα 3 απεικονίζεται η διαχρονική εξέλιξη του ετήσιου αριθμού των ημερών με υπέρβαση της ημερήσιας οριακής τιμής.

Στο πλαίσιο διερεύνησης των επιπτώσεων της μεταφοράς σκόνης από τη Σαχάρα στην εργασία των Proias *et al.* (2009b) αναλύθηκαν περιπτώσεις επεισοδίων μεταφοράς σκόνης από τη Σαχάρα στη διάρκεια της περιόδου 2005-2007. Στη διάρκεια της 3-ετούς αυτής περιόδου καταγράφηκαν οκτώ επεισόδια. Ειδικότερα, μελετήθηκαν οι επιδράσεις τους στη διαμόρφωση των επιπέδων συγκέντρωσης των ημερήσιων τιμών συγκέντρωσης των PM_{10} στο σταθμό του Βόλου.



Σχήμα 3: Διαχρονική εξέλιξη του αριθμού των ημερών με υπέρβαση της ημερήσιας οριακής τιμής των 50 μg/m^3, κατά την περίοδο 2001-2010. Η οριζόντια γραμμή αντιστοιχεί στο ετήσιο μέγιστο επιτρεπτό αριθμό υπερβάσεων (EU 1999).

Στην παρούσα εργασία, γίνεται μία πρώτη παρουσίαση των αποτελεσμάτων που αφορούν τη χημική σύσταση των αιωρούμενων σωματιδίων στην πόλη του Βόλου. Τα αποτελέσματα που εμφανίζονται στον Πίνακα 1, αφορούν τη χημική ανάλυση του κλάσματος των εισπνεύσιμων (PM_{10}) και των αναπνεύσιμων ($PM_{2.5}$) αιωρούμενων σωματιδίων στο Βόλο, σε δύο χρονικές περιόδους που καλύπτουν τη θερμή περίοδο (Αύγουστος 2011) και την ψυχρή περίοδο (Φεβρουάριος 2012) του έτους.

Οι μέσες εποχικές τιμές και το αντίστοιχο εύρος τόσο του οργανικού όσο και του στοιχειακού άνθρακα (Πίνακας 1) συγκρίνονται με τα επίπεδα τιμών που αναφέρονται στη διεθνή βιβλιογραφία (Ruellan and Cachier 2001, Salma *et al.* 2004, Hueglin *et al.* 2005, Viana *et al.* 2006) από μετρήσεις σε άλλες ευρωπαϊκές πόλεις.

Οι εποχικές τιμές του λόγου OC/EC για τα PM_{10} κυμάνθηκαν μεταξύ 6.70 και 22.07 (Πίνακας 1) δείχνουν μια σαφή υπεροχή του οργανικού έναντι του στοιχειακού άνθρακα, γεγονός που αναδεικνύει πιθανό δευτερογενή σχηματισμό οργανικών αερολυμάτων. Από τη διεθνή βιβλιογραφία, για αστικές περιοχές έχουν καταγραφεί τυπικές τιμές του λόγου OC/EC να κυμαίνονται μεταξύ 1 και 4 (μεταξύ άλλων Wang *et al.* 2005). Η διακύμανση των τιμών του λόγου OC/EC μπορεί να χρησιμοποιηθεί ως δείκτης των αλλαγών στις πηγές εκπομπών ή των διαδικασιών, δεδομένου ότι πηγή της Ε.Ε. θεωρείται σαν ενδεικτικό ίχνος για πρωτογενείς εκπομπές (ατελείς καύσεις). Σε ανάλογη μελέτη που πραγματοποιήθηκε στην πόλη της Θεσσαλονίκης (Terzi *et al.* 2010) οι τιμές του λόγου OC/EC ήταν υψηλότερες κατά τη διάρκεια του χειμώνα, ωστόσο, το γεγονός ότι η υψηλή τιμή του λόγου αποδίδεται στη μείωση της τιμής του στοιχειακού άνθρακα παρά στην αύξηση του οργανικού άνθρακα. Το γεγονός αυτό αποτελεί ένδειξη πιθανών αλλαγών σε πηγές εκπομπών και απαιτείται περαιτέρω διερεύνηση.

Πίνακας 1: Μέσες τιμές συγκέντρωσης (μg/m^3), με τι μορφή μέση τιμή ± τυπική απόκλιση, οργανικού άνθρακα (OC), στοιχειακού άνθρακα (EC) και των λόγων τους σε $PM_{2.5}$ και PM_{10} στο Βόλο.

	$PM_{2.5}$		**PM_{10}**	
	Χειμώνας	**Καλοκαίρι**	**Χειμώνας**	**Καλοκαίρι**
OC	30.70±1.73	16.80±1.04	33.10±1.85	20.10±1.21
EC	3.37±0.37	2.36±0.32	1.50±0.41	3.00±0.35
OC/EC	9.11	7.12	22.07	6.70

Όσον αφορά τις εποχικές τιμές του λόγου OC/EC για τα $PM_{2.5}$ κυμάνθηκαν μεταξύ 7.12 και 9.11 (Πίνακας 1) δείχνουν και στην περίπτωση αυτή μια σαφή υπεροχή του οργανικού έναντι του στοιχειακού άνθρακα. Από τη διεθνή βιβλιογραφία, για αστικές περιοχές υποβάθρου έχουν καταγραφεί υψηλές τιμές του λόγου OC/EC που κυμαίνονταν μεταξύ 8.8 για το χειμώνα (Lonati *et al.* 2005) και 12 για την άνοιξη (Salma *et al.* 2004). Επίσης, σε αγροτικές περιοχές έχουν καταγραφεί υψηλές τιμές του λόγου OC/EC που κυμαίνονταν μεταξύ 8 και 12, για το χειμώνα και την άνοιξη, αντίστοιχα (Decesari *et al.* 2001).

5. ΣΥΜΠΕΡΑΣΜΑΤΑ

Στην εργασία αυτή μελετήθηκαν οι συγκεντρώσεις των αιωρουμένων σωματιδίων αεροδυναμικής διαμέτρου μικρότερης των 10 μm (PM_{10}) και μικρότερης, αυτής των 2.5μm ($PM_{2.5}$) από τέσσερις διατάξεις δειγματοληψίας αερολύματος σε κατάλληλα φίλτρα και από τον σταθμό μέτρησης της Περιφερειακής Ενότητας Μαγνησίας και Σποράδων εγκατεστημένο στο κέντρο του αστικού ιστού της πόλης. Οι περίοδοι μελέτης καλύπτουν τη θερμή περίοδο του έτους 2011 (Αύγουστος) και την ψυχρή περίοδο του έτους 2012 (Φεβρουάριος). Ειδικότερα, η μελέτη εστιάσθηκε στην παρουσίαση των αποτελεσμάτων που αφορούν τη χημική σύσταση των αιωρούμενων σωματιδίων στην πόλη του Βόλου.

Από την ανάλυση των στοιχείων διαπιστώθηκε ότι οι μέσες εποχικές τιμές και το αντίστοιχο εύρος τόσο του οργανικού όσο και του στοιχειακού άνθρακα είναι συγκρίσιμα με τα επίπεδα τιμών που αναφέρονται στη διεθνή βιβλιογραφία από μετρήσεις σε άλλες ευρωπαϊκές πόλεις.

Οι εποχικές τιμές του λόγου OC/EC τόσο για τα PM_{10}, όσο και τα $PM_{2.5}$ δείχνουν μια σαφή υπεροχή του οργανικού έναντι του στοιχειακού άνθρακα, γεγονός που αναδεικνύει πιθανό δευτερογενή σχηματισμό οργανικών αερολυμάτων. Ειδικότερα, οι τιμές του λόγου OC/EC για τα PM_{10} κυμάνθηκαν μεταξύ 6.70 και 22.07, ενώ οι αντίστοιχες για τα $PM_{2.5}$ κυμάνθηκαν μεταξύ 7.12 και 9.11.

Τέλος, οι τιμές του λόγου ήταν υψηλότερες κατά τη διάρκεια του χειμώνα, και στις δύο περιπτώσεις, γεγονός που υποδηλώνει ότι η υψηλή τιμή του λόγου αποδίδεται περισσότερο στη μείωση της τιμής του στοιχειακού άνθρακα παρά στην αύξηση του οργανικού άνθρακα. Το γεγονός αυτό αποτελεί ένδειξη πιθανών αλλαγών σε πηγές εκπομπών και για την απόδειξή του απαιτείται περαιτέρω διερεύνηση.

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Generalizing Total Pollution Cost

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Abstract
Relying on Pigou's view, environmental taxes increase the costs of polluting activities reflecting in this way the true social cost imposed to society by the caused environmental damage by these activities. The total pollution cost (TPC) is defined by adding up the marginal abatement (MAC) and the marginal damage (MD) costs. That is the random variable TPC includes the social costs associated with pollution. We relate this with contaminated locations and propose a weighted location differentiated tax. It is clear that the value of the expected total pollution (social) cost, E(TPC), would be of interest and therefore we proceed to the evaluation through the use of the γ-order Generalized Normal. The value of the variance, Var(TPC), is also evaluated.

Keywords: Weighted-location adjusted differential tax; total pollution cost; expected value γ-order Normal distribution.

JEL Classifications: C02; C60; Q50; Q53; Q58.

1. Introduction

In the past, command and control regulations (like limiting the use of specific fuels or demanding certain pollution sources to use specific methods) dominated environmental policies with market based instruments (like taxes and tradable permits) to dominate over the last decades. Environmental taxation relies on Pigou’s concept of increasing polluters’ private costs to a level that includes the associated true social costs imposed to the society by their activities and the resulting related environmental damages.

Economic theory indicates that the optimal tax rate is determined where marginal abatement cost (MAC) equals to marginal damage cost (MD) of pollution to be abated. But firms do not have always an incentive to reveal their true abatement costs. A weighted location adjusted differentiated taxation is introduced, based on the principle that when pollution is above “an optimal and accepted level” more taxation has to be imposed, while if it is below there is a chance of less taxation. In this way a new index to adjust taxation to the damage caused is proposed.

Given innovation outcome (X), the Total Pollution Cost (TPC) is defined by the sum of the marginal abatement (MAC) and the marginal damage (MD) costs. That is the random variable TPC includes the social costs associated with pollution. In this paper we evaluate the expected value of TPC and introduce the estimation of its variance. Specifically, choosing as TPC the general form TPC= $(\kappa X+\lambda)^2$ (with κ, λ constants and X the introduced technology) coming from the γ-order generalized normal distribution we provide a generalization of the E(TPC) both in the form of TPC and the probability density function. The introduced technology is represented by X. In this way we propose a weighted location differentiated taxation to existing tax systems and a corresponding ratio to provide us with an index adjusting taxation to the damage imposed.

2. The weighed location adjusted differential tax

The way we move on is by defining the "weighted location differential tax". Theoretically this tax will be non-linear (since high pollutants should face appropriate taxes i.e. exponential greater and not linear) and non–time consistent (as pollution is not time constant depending for instance on weather conditions, amount of production, etc). This new indicator for environmental policy is based on a generalization of the differential taxation (Halkos, 1993, 1994; Kim and Chang, 1993; Mc Kitrick, 1999) and provides another look of differentiation in taxation, based on the location and the assumed distribution the new introduced technologies follow (see the definition of TPC before).

Our argument is that around the pollution center (*source of pollution*) the pollution is distributed according to a (possible) statistical model, related with the actual situation. In such a case it may be uniformly distributed i.e. in a distance, left or right from the pollution center, the pollution to remain constant. That might be a helpful, mathematically, assumption, but it is difficult to be true. Another approach is
to consider a normally distributed pollution, with the mean being at the pollution center, so plus or minus it one standard deviation concentrates approximately the 0.68 of the pollution. In cases of 0.99 levels of pollution concentration we may consider a ±3σ confidence interval (or L=6σ) as essential. This is near to be true, as the tails contain a very small probability level to allow a pollution influence.

Similarly, the Laplace distribution offers a solution to provide a "strong" pollution center and fat tails. All these three distributions are special cases of the γ- order Generalized Normal distribution.

We remind that the normal distribution $\mathrm{N}(\mu,\sigma^2)$, with mean μ and variance σ^2, is defined as:

$$f(x)=\frac{1}{(2\pi)^{\frac{1}{2}}\sigma}\exp\left\{-\frac{1}{2\sigma^2}(\chi-\mu)^2\right\} \qquad (1)$$

The multivariate generalization for a multivariate random variable with p-conditions, μ mean and matrix covariance Σ is:

$$\varphi(\chi)=\frac{1}{(2\pi)^{\frac{p}{2}}|\Sigma|^{\frac{1}{2}}}\exp\left\{-\frac{1}{2}(\chi-\mu)^{\mathrm{T}}\Sigma^{-1}(\chi-\mu)\right\} \tag{2}$$

We denote with $N_p(\mu,\Sigma)$, $|\Sigma|$=det(Σ).

Kitsos and Tavoularis (2009) introduced through Logarithm Sobolev Inequalities (LSI) a new family of univariate γ-ordered Normal distribution, the $\mathrm{N}_{\gamma}^{\rho}(\mu,\Sigma)$, which generalize the Normal Distribution $\mathrm{N}^{\rho}(\mu,\Sigma)$, through an additional parameter $\gamma\in\mathbb{R}-[0,1]$. The new generalized Normal distribution commonly referred to as Normal distribution γ-ordered is defined. Specifically, when $f(x)$ is the probability density function of a random variable $\mathrm{X}\sim\mathrm{N}_{\gamma}^{\rho}(\mu,\Sigma)$ then, compared with (2) above, $f(x)$ is defined as :

$$f_{\gamma}(x;\mu\Sigma)=C_{\gamma}^{p}\left|\det\Sigma\right|^{-\frac{1}{2}}\exp\left\{-\frac{\gamma-1}{\gamma}\left[Q(x)\right]^{\frac{\gamma}{2(\gamma-1)}}\right\} \text{ with } x\in\mathbb{R}^{\rho}, \tag{3}$$

Where $Q(x)=(x-\mu)\Sigma^{-1}(x-\mu)^{\mathrm{T}}$ as in (2) with the normality factor

$$C_{\gamma}^{p}=\pi^{-\frac{p}{2}}\frac{\Gamma(\frac{p}{2}+1)}{\Gamma(p\frac{\gamma-1}{\gamma}+1)}\left(\frac{\gamma-1}{\gamma}\right)^{p\frac{\gamma-1}{\gamma}} \tag{4}$$

Setting γ=2 i.e. $\mathrm{N}_{2}^{\rho}(\mu,\Sigma)$ it follows that :

$$C_{2}^{p}=\pi^{-\frac{p}{2}}\frac{\Gamma(\frac{p}{2}+1)}{\Gamma(\frac{p}{2}+1)}\left(\frac{1}{2}\right)^{p}=(2\pi)^{-\frac{p}{2}}=\frac{1}{2\pi^{\frac{p}{2}}} \tag{5}$$

In this particular distribution, the third involved parameter, the shape one called γ, taking all real values but not within [0,1], offers a number of different distributions with fat tails mainly. With the value of γ=1, it is reduced to Uniform; with the value γ=2 is reduced to Normal; and with the value of γ "infinity", practically very large, is Laplace.

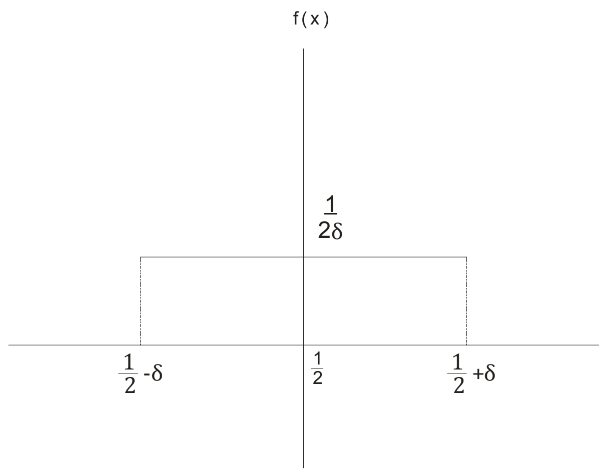
3. Adopting the appropriate distribution

The easiest way, as far as the mathematical calculations are concerned, despite its unrealistic character, is to assume that the stochastic variable X –as a result of the R&D

procedure, is uniformly distributed in the interval $\left[\frac{1}{2}-\delta, \frac{1}{2}+\delta\right]$, say, recalling the definition of the Uniform distribution. This means that in this research we suppose eventually the variable TPC is derived from the Uniform distribution, i.e. $u\left(\frac{1}{2}-\delta, \frac{1}{2}+\delta\right)$ implying a uniform density function for X of the form

$$f(X)=\frac{1}{2\delta} \quad \text{for} \quad X \in \left[\frac{1}{2}-\delta, \frac{1}{2}+\delta\right] \tag{6}$$

The graph of $f(x)=\frac{1}{2\sigma}$ with μ = $\frac{1}{2}$ and σ = δ is presented next:



From the definition of the expected value the pollution related t- social cost for the linear tax, $\mathrm{E}\left[TPC_{t_l}\right]$, is equal to $\int_{\frac{1}{2}-\delta}^{\frac{1}{2}+\delta} TPC\, f(x)dx$. Any general form of TPC= $(\kappa X+\lambda)^2$ is presenting the appropriate area for TPC.

An extension of the calculation of expected value is needed as it can be either normal with the known tails or a "sharp" one around 'center' with 'heavy tails', a Laplace distribution among others. Therefore the γ-order generalized Normal distribution was adopted as the extension of the Uniform distribution. The expected value of TPC can be evaluated and it can be seen that that the distribution is not only the Uniform but the $\mathrm{N}_{\gamma}(\mu,\sigma^2)$.

Theorem 1: It holds that the multivariate γ-ordered Normal distribution $\mathrm{N}_{\gamma}^{\rho}(\mu,\Sigma)$ for order values of γ=1,2 $\pm\infty$ coincides with

$$\mathrm{N}_{\gamma}^{\rho}(\mu,\Sigma)=\begin{cases} D^{\rho}(\mu) & \gamma=0 \quad p=1,2 \quad \textit{Dirac} \quad \textit{distribution} \\ U^{\rho}(\mu,\Sigma) & \gamma=1 \quad \textit{Uniform} \quad \textit{distribution} \\ \mathrm{N}^{\rho}(\mu,\Sigma) & \gamma=2 \quad \textit{Normal} \quad \textit{distribution} \\ L^{\rho}(\mu,\Sigma) & \gamma=\pm\infty \quad \textit{Laplace} \quad \textit{distribution} \end{cases}$$

Proof: In Kitsos et.al. (2012, page 52).

So, the following results are proposed for the form $(\kappa g+\lambda)^2$ and $f_{\gamma}(\mathrm{x};\mu,\Sigma)$ letting X represent a random variable describing innovation.

***Proposition 1**:* If $\mathrm{X}\sim\mathrm{N}_{\gamma}(\mu,\sigma^2)$ it holds that:

$$\mathrm{E}\left[(\kappa\mathrm{X}+\lambda)^2\right]=\left(\frac{\gamma}{\gamma-1}\right)^{2\frac{\gamma-1}{\gamma}}\frac{\Gamma(3\frac{\gamma-1}{\gamma})}{\Gamma(\frac{\gamma-1}{\gamma})}(\kappa\delta)^2+\kappa\mu(\kappa\mu+2\lambda)+\lambda^2 \tag{7}$$

$$Var((\kappa\mathrm{X}+\lambda^2))=\left(\frac{\gamma}{\gamma-1}\right)^{4\frac{\gamma-1}{\gamma}}(\kappa\delta)^4\left[\frac{\Gamma(5\frac{\gamma-1}{\gamma})}{\Gamma(\frac{\gamma-1}{\gamma})}-4\frac{\Gamma^2(3\frac{\gamma-1}{\gamma})}{\Gamma^2(\frac{\gamma-1}{\gamma})}\right]-(\kappa\mu)^3(\kappa\mu+4\lambda)$$

$$+2(\kappa\delta)^2\left[2\lambda^2-(\kappa\mu)^2-2\kappa\lambda\mu\right]\left(\frac{\gamma}{\gamma-1}\right)^{\frac{2\gamma-1}{\gamma}}\frac{\Gamma(3\frac{\gamma-1}{\gamma})}{\Gamma(\frac{\gamma-1}{\gamma})} \tag{8}$$

Proof: We have seen that

$$\mathrm{E}[(\kappa X+\lambda)^2]=\kappa^2\mathrm{E}[X^2]+2\kappa\lambda\mathrm{E}[X]+\lambda^2=\kappa^2\left(\mathrm{Var}(X)+\mathrm{E}^2[X]\right)+2\kappa\lambda\mathrm{E}[X]+\lambda^2,$$

Assuming $X\sim\mathcal{N}_{\gamma}(\mu,\delta^2)$ and using the variance of γ-order Normal distribution, (see Kitsos and Toulias, 2010) we have that

$$\mathrm{E}[(\kappa X+\lambda)^2]=\kappa^2\left(\mathrm{Var}(X)+\mu^2\right)+2\kappa\lambda\mu+\lambda^2 .$$

For the variance of $Y=(\kappa X+\lambda)^2$ we have

$$\begin{aligned}\mathrm{Var}(Y)&=\mathrm{E}[Y^2]-\mathrm{E}^2[Y]=\mathrm{E}[(\kappa X+\lambda)^4]-\mathrm{E}^2[(\kappa X+\lambda)^2]=\\&=\kappa^4\mathrm{E}[X^4]+4\kappa^3\lambda\mathrm{E}[X^3]+6(\kappa\lambda)^2\mathrm{E}[X^2]+4\kappa\lambda^3\mathrm{E}[X]+\lambda^4-\mathrm{E}^2[(\kappa X+\lambda)^2]=\\&=\kappa^4\mathrm{Kurt}(X)\mathrm{Var}^2(X)+6(\kappa\lambda)^2\mathrm{Var}(X)+6(\kappa\lambda\mu)^2+4\kappa\lambda^3\mu+\lambda^4-\mathrm{E}^2[(\kappa X+\lambda)^2]\end{aligned}$$

As $\mathrm{E}[X^3]=0$ ($\mathcal{N}_\gamma(\mu,\delta^2)$ is symmetric distribution (i.e. has zero obliquity), thus eventually, the above equation can be written sequentially as

$$\begin{aligned}\mathrm{Var}(Y)=&\ \kappa^4\mathrm{Kurt}(X)\mathrm{Var}^2(X)+6(\kappa\lambda)^2\mathrm{Var}(X)+6(\kappa\lambda\mu)^2+4\kappa\lambda^3\mu+\lambda^4\\&-\left[\kappa^2\left(\mathrm{Var}(X)+\mu^2\right)+2\kappa\lambda\mu+\lambda^2\right]^2=\\&=\kappa^4\mathrm{Kurt}(X)\mathrm{Var}^2(X)+6(\kappa\lambda)^2\mathrm{Var}(X)+6(\kappa\lambda\mu)^2+4\kappa\lambda^3\mu+\lambda^4\\&-\kappa^4\left(\mathrm{Var}(X)+\mu^2\right)^2-4(\kappa\lambda\mu)^2-\lambda^4\\&-4\kappa^3\lambda\mu\left(\mathrm{Var}(X)+\mu^2\right)-2(\kappa\lambda)^2\left(\mathrm{Var}(X)+\mu^2\right)-4\kappa\lambda^3\mu=\\&=\kappa^4\mathrm{Kurt}(X)\mathrm{Var}^2(X)+6(\kappa\lambda)^2\mathrm{Var}(X)+6(\kappa\lambda\mu)^2+4\kappa\lambda^3\mu+\lambda^4\\&-\kappa^4\mathrm{Var}^2(X)-(\kappa\mu)^4-2\kappa^4\mu^2\mathrm{Var}(X)-4(\kappa\lambda\mu)^2-\lambda^4\\&-4(\kappa\mu)^3\lambda-4\kappa^3\lambda\mu\mathrm{Var}(X)-2(\kappa\lambda)^2\mathrm{Var}(X)-2(\kappa\lambda\mu)^2-4\kappa\lambda^3\mu\end{aligned}$$

And so

$$\mathrm{Var}(Y)=\kappa^4[\mathrm{Kurt}(X)-1]\mathrm{Var}^2(X)+[4(\kappa\lambda)^2-2\kappa^4\mu^2-4\kappa^3\lambda\mu]\mathrm{Var}(X)-(\kappa\mu)^3(\kappa\mu+4\lambda)$$

Since $X\sim\mathcal{N}_\gamma(\mu,\delta^2)$, the above equation can be written finally in the form of (8) using the variance and the convexity of the γ-order Normal distribution (for more details see Kitsos and Toulias, 2010).

With different values of κ and λ a number of calculations for the corresponding TPC can be obtained. Next we present a number of examples.

Example 1*:* Let us assume that TPC = $(1/4-3/8X)^2$. Then it holds:

$$\mathrm{E}[\mathrm{TPC}_{\hat{i}_\ell;\gamma}]=\tfrac{1}{4}+9\left(\tfrac{\gamma}{\gamma-1}\right)^{2\frac{\gamma-1}{\gamma}}\frac{\Gamma(3\frac{\gamma-1}{\gamma})}{\Gamma(\frac{\gamma-1}{\gamma})}\delta \tag{9}$$

$$\mathrm{Var}\left(TPC_{\hat{i}_\ell;\gamma}\right)=\begin{cases}13\frac{27}{4}+318\delta-\frac{11}{45}(36\delta)^2, & \gamma=1,\\ 13\frac{27}{4}+954\delta-(18\delta)^2, & \gamma=2,\\ 13\frac{27}{4}+1908\delta+2(6\delta)^2, & \gamma=\pm\infty.\end{cases} \tag{10}$$

Example 2: Based on Example 1, for this particular TPC, it holds that the expected value and variance of TPC can be evaluated for the Uniform, Normal and Laplace distributions as:

$$\mathrm{E}[\mathrm{TPC}_{\hat{t}_\ell;\gamma}] = \begin{cases} \frac{1}{4}+3\delta, & \gamma=1, \\ \frac{1}{4}+9\delta, & \gamma=2, \\ \frac{1}{4}+18\delta, & \gamma=\pm\infty, \end{cases} \tag{11}$$

$$\mathrm{Var}\left(TPC_{\hat{t}_\ell;\gamma}\right) = \begin{cases} 13\frac{27}{4}+318\delta-\frac{11}{45}(36\delta)^2, & \gamma=1, \\ 13\frac{27}{4}+954\delta-(18\delta)^2, & \gamma=2, \\ 13\frac{27}{4}+1908\delta+2(6\delta)^2, & \gamma=\pm\infty. \end{cases} \tag{12}$$

Example 3**:** From (11) it obviously holds that the quantity $\mathrm{E}\left[TPC_{t_l,\gamma}\right]$ in the case of Uniform distribution is less than the corresponding Normal distribution, which is less that the corresponding Laplace distribution. That is:

$$\mathrm{E}\left[TPC_{t_l,1}\right] < \mathrm{E}\left[TPC_{t_l,2}\right] < \mathrm{E}\left[TPC_{t_l,\pm\infty}\right]$$

For (12) and for $0<\delta<49.074$ it holds that :

$$Var^U(\mathrm{TPC}) < Var^N(\mathrm{TPC}) < Var^L(\mathrm{TPC})$$

3.1 Checking the difference in variances

Evaluating the difference between the variance of Uniform, Normal and Laplace distribution we may see which are positive or negative, so that to rearrange the order among them.

(A) Between Uniform and Normal (take the difference from (12))

$$12.96\delta^2 - 636\delta = 0 \Leftrightarrow$$

$$\delta(12.96\delta - 636) = 0 \Leftrightarrow \begin{cases} \delta = 0 \\ \delta = \dfrac{636}{12.96} = 49.074 \end{cases}$$

$$U - N = \begin{cases} >0 & \delta<0, \delta>49.074 \\ <0 & 0<\delta<49.074 \end{cases}$$

The Normal distribution is greater than the Uniform distribution when $\delta \in (0, 49.074)$. Otherwise, when $\delta > 49.074$, the Uniform distribution of TPC is greater than the Normal distribution.

$$Var^U(\text{TPC}) < Var^N(\text{TPC})$$

$$0 < \delta < 49.074$$

(B) Between Laplace and Normal (take the difference from (12))

$$-954\delta - 396\delta^2 = 0$$

$$\delta(396\delta + 954) = 0 \Leftrightarrow \begin{cases} \delta = 0 \\ \delta = -\dfrac{954}{396} = -2.40 \end{cases}$$

$$N - L = \begin{cases} < 0 \;\; \delta \in (-2.40, 0) \\ > 0 \;\; \delta < -2.40 \quad or \;\; \delta > 0 \end{cases}$$

Because δ is taken always positive, we are interested in the case where δ>0, so the Normal distribution is greater than the Laplace distribution.

$$Var^N(TPC) < Var^L(TPC)$$

(C) Between Uniform and Laplace (take the difference form (12))

$$-1590\delta - 383.04\delta^2$$

$$= -\delta(383.04\delta + 1590) \Leftrightarrow \begin{cases} \delta = 0 \\ \delta = -\dfrac{1590}{383.04} = -4.15 \end{cases}$$

$$U - L = \begin{cases} > 0 \;\; \delta \in (-4.15, 0) \\ < 0 \;\; \delta < -4.15 \quad or \;\; \delta > 0 \end{cases}$$

So, for δ>0, the TPC Uniform distribution is less than the Laplace distribution.

$$Var^U(\text{TPC}) < Var^L(\text{TPC})$$

From (A), (B) and (C) we have that for $0 < \delta < 49.074$ holds:

$$Var^{U}\,(\text{TPC}) < Var^{N}\,(\text{TPC}) < Var^{L}\,(\text{TPC})$$

4. Discussion and policy implications

Environmental taxes should be targeted to the pollutants and should be related to the environmental damage caused. Without any government intervention countries (firms) will not take into consideration any environmental damage caused as this maybe either spread across different regions or countries (as in the case of trans frontier pollution) or may be accumulated (stock pollution). The way to cope with the problem is to tax directly the environmental damage costs due to the damages imposed.

Specifically, in this research we have considered a general distribution that the random variable X of the new technologies adopted by a firm, and therefore the total pollution cost (TPC) follows it covering 3 different lines. Due to this general distribution a weighted location differential tax was introduced. It has been shown the application of the γ-ordered generalized Normal, provides to the researcher the option to choose among three distributions: Uniform, Normal and Laplace.

If the relationship between source and receptor locations is not considered then the externality imposed will not be taken into examination. The externality is considered by the appropriate consideration of the transfer coefficients as provided by the co-operative program for monitoring and evaluation of the long range transmission of air pollutants in Europe (European Monitoring and Evaluation Program, EMEP). Then mathematical models may be used by policy makers to define the optimal necessary emissions reductions for each pollution source (country) i and under the ecosystem sensitivity thresholds (see among others Halkos, 1994).

Acknowledgments
This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: Heracleitus II. Investing in knowledge society through the European Social Fund.

European Union
European Social Fund
OPERATIONAL PROGRAMME
EDUCATION AND LIFELONG LEARNING
investing in knowledge society
MINISTRY OF EDUCATION & RELIGIOUS AFFAIRS
MANAGING AUTHORITY
Co- financed by Greece and the European Union
NSRF 2007-2013
programme for development
EUROPEAN SOCIAL FUND

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The effect of economic growth and government expenditure on the environment: evidence using distributed lag models

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Abstract
This paper examines the effect of economic growth and government spending on the environment using a panel of 71 countries for the time period 1970-2008. In particular, we test the hypothesis of the existence of an inverted U-shaped relationship between economic performance and pollution, as well as the hypothesis of a negative direct relationship between pollution and fiscal spending. To take into account that environmental degradation may respond to changes in income and government spending with a time lag, due to technological and institutional reasons, we apply appropriate dynamic econometric methods. We report the estimates for both the short-run and long-run effects on two different air pollutants, namely SO_2 and CO_2, and we distinguish the results for different levels of economic development. Policy implications range depending on the level of income of the considered countries.

Keywords: Government expenditure; economic growth; environment; dynamics

JEL Classification Codes: E60; Q53; Q54; Q56.

1. Introduction

The purpose of this paper is twofold, namely to examine the effect of economic growth as well as that of government expenditure on environmental degradation, taking into account the dynamic nature of these relationships. The environmental Kuznets curve (hereafter EKC) hypothesis posits that in the early stages of economic development environmental degradation will increase until a certain level of income is reached and then environmental improvement will occur (Gross and Krugman, 1995). On the other hand, government expenditure has recently expanded in many countries to alleviate the adverse effects of the recent economic crisis, with a large fraction of GDP spent by governments affecting a variety of economic variables and prosperity in general. A recent strand of literature suggests that government spending is an important determinant of environmental quality (Lopez et al., 2011, Halkos and Paizanos, 2013; Galinato and Islam, 2014).

According to Halkos (2003) EKC studies identify several factors as the most important in determining the inverted-U shape of the curve. In particular, improvements in environmental quality occurring from advances in production technology, the exportation of ‘dirty industry’ to less developed countries, the role of preferences and regulation on the emissions profile of polluters, the better institutional set up in the form of credible property rights, regulations and good governance which may create public awareness against environmental degradation and finally, the technological link between the consumption of a desired good and the abatement of its undesirable by-products in the form of pollution.

On the other hand, the mechanisms through which government expenditure and environment interact with each other are investigated in theoretical papers by Heyes (2000), Lawn (2003) and Sim (2006). Higher government expenditure is more likely to include redistributive transfers, which result to increased income equality and thus to higher demand for environmental quality. Moreover, if the environment is a luxury public good, it is likely that it will only be demanded when the demand for other public goods has been satisfied, i.e. at large levels of government size (Frederik and Lundstrom, 2001). Lopez et al. (2011) identify four mechanisms by which the level and composition of fiscal spending may affect pollution levels[25], namely the scale (increased environmental pressures due to more economic growth), composition (increased human capital intensive activities instead of physical capital intensive industries that harm the environment more), technique (due to higher labor efficiency) and income (where increased income raises the demand for improved environmental quality) effects.

However, in examining the aforementioned relationships their dynamic nature should be taken into account. In particular, it is highly unlikely that the above effects of income and government spending on the environment occur instantaneously (Halkos, 2003; Lopez et. al., 2011) and this may occur for several reasons. For example, technological advances that usually accompany economic development may take several years until fully implemented by industries. In addition, for psychological reasons and as a result of the force of habit (inertia), industries and consumers may not alter their production methods and habits immediately following a technological advance or a distributional effect from a change in public spending, a result that may also sometimes be augmented by imperfect knowledge. Finally, one may expect institutional reasons to also contribute to lags.

Given this background, our purpose is to investigate first how increases in income and government spending affect pollution at given income levels in the short-run, and then to estimate how this changes influence environmental quality in the long-term.

To the best of our knowledge the present paper is the first that explicitly studies the short-run as well as the long-run effects of both economic development and government expenditure on the environment. For that reason, we estimate an augmented EKC equation, employing a sample of 71 countries covering the period 1970-2008 for two air pollutants (sulfur dioxide, SO_2 and carbon dioxide, CO_2). In estimating the proposed model we take into account the dynamic nature of the relationships examined, by employing appropriate econometric methods for the estimation of dynamic panels.

The remainder of the paper is organized as follows: Section 2 presents the data used in the analysis and section 3 discusses the proposed econometric models. The empirical results are reported in section 4 while the final section concludes the paper.

[25] In particular, they examine the effect of the share of public goods in total government expenditure on pollution.

2. Data

Our sample consists of 71 countries[26] with a full set of SO_2, CO_2, GDP/c and share of government expenditure, for the period 1970-2008. The analysis for SO_2 takes place up to the year 2003 because of limited availability of data on this pollutant after that period. The data for SO_2 and CO_2 are from Stern (2005) and Boden et. al. (2011) respectively, the data on national income from Maddison (2010) and finally the data on government share of income were collected from the Penn World Table (2009). The database consists of up to 2,698 observations per variable.

To avoid dependence of results on geographic location characteristics and atmospheric conditions, emissions of the two pollutants were used rather than their concentrations. An important distinction between the two pollutants that has to do with their atmospheric life characteristics is their geographical range of effect (Cole, 2007). Considering that two-thirds of SO_2 moves away from the atmosphere within 10 days after its emission, its impact is mainly local or regional and thus, historically, sulfur dioxide has been subject to regulation. In contrast, CO_2 has not been regulated by governments, since its atmospheric life varies from 50 to 200 years and hence its impact is global.

The sources of pollution vary by pollutant. The main sources of SO_2 emissions are electricity generation and industrial processes. On the other hand, apart from energy transformation and industry, an important source of CO_2 emissions is transport. Apparently SO_2 pollution is characterized as production-generated, while CO_2 emissions are a mix between production and consumption–generated pollution. This distinction is important since the mechanism by which government expenditure size affects consumption pollution is likely to differ compared to production pollution. SO_2 emissions can be decreased by reducing consumption of fossil fuels (especially high-sulfur content coal), by using smoke-scrubbing equipment in power plants and by increasing energy efficiency. However, in consumption related pollutants the use and influence of environmental policies is more difficult, since the main tool to reduce these is the implementation of environmental taxes, which are often avoided as they are not politically popular.

3. Methodology

To establish the relationship between air pollution and GDP/c, Box-Cox tests have been performed to test linearity against logarithmic functional forms. Implementation of the Akaike and Bayesian information criteria indicated that the appropriate use of powers of the income variable is three, thus we use a cubic specification. In addition, employing greater powers of the income variable leads to multicollinearity among the explanatory variables. Specifically, findings of the tests lead us to propose the following model which

[26]Albania, Angola, Argentina, Australia, Austria, Belgium, Bolivia, Brazil, Bulgaria, Canada, Chile, China, Colombia, Denmark, Djibouti, Equador, Egypt, El Salvador, Ethiopia, Finland, France, Ghana, Greece, Guatemala, Guinea Bissau, Honduras, Hungary, India, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Lebanon, Liberia, Madagascar, Mauritius, Mexico, Mongolia, Morocco, Mozambique, Netherlands, New Zealand, Nigeria, Norway, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Sierra Leone, South Africa, Spain, Sri Lanka, Sudan, Sweden, Switzerland, Syria, Thailand, Trinidad, Tunisia, Turkey, Uganda, United Kingdom, United States, Uruguay

represents a conventional cubic formulation of the EKC, augmented by the lagged share of government expenditure over income:

$$\ln(P/c)_{it} = \mu_i + \zeta_t + \beta_1 \ln Govshare_{it-1} + \beta_2 \ln(GDP/c)_{it} + \beta_3 (\ln(GDP/c))^2_{it} + $$
$$+ \beta_4 (\ln(GDP/c))^3_{it} + \varepsilon_{it} \qquad (1)$$

where subscripts i and t represent country and time respectively and all variables are expressed in natural logarithms, unless otherwise stated.

The income variable and its powers in (1) control for scale effects. The term μ_i is a country effect which can be fixed or random, ζ_t is a time effect common to all countries and ε_{it} is a disturbance term with the usual desirable properties. Following the terminology used to classify the pollution effects in the trade literature, the coefficient on the government expenditure variable captures the composition, income and part of the technique effect.

3.1 Econometric issues and estimation

In estimating equation (1) we must take into account the unobserved heterogeneity across countries. The standard approach is to use fixed and random effects, hereafter FE and RE respectively, model formulations with the choice depending on the assumption adopted about the correlation between the cross-section specific error-component and the explanatory variables. When such correlation is present, then RE estimators are not consistent and efficient and the use of FE is more appropriate. For instance, in the pollutants equations these country-specific characteristics may include differences in climate, geography and fossil fuels endowments, all of them potentially correlated with emissions (Leitao, 2010). Additionally, it is very likely that country unobserved characteristics are correlated with income and the other explanatory variables, implying that FE estimation is preferred. This assumption is supported by the use of Hausman test, in which the RE model was rejected in favor of the FE model, for equation (1) in all cases.

Since the balanced panel data used in this paper consists of large N and T dimensions, non-stationarity is important. We are particularly concerned about the dynamic misspecification of the pollutants equations. In particular, if we rely on a static model, then all adjustments to any shock occur within the same time period in which they occur, but this could be justified only in equilibrium or if the adjustment mechanism is rapid. According to Perman and Stern (1999) this is extremely unlikely and instead, it is expected that the return to long-run equilibrium emission levels is a rather slow process.

To estimate a non-stationary dynamic panel we employ the dynamic fixed effects (DFE) estimator developed by Pesaran and Smith (1995) and Pesaran et al. (1997, 2004). In DFE estimation we assume that intercepts differ across countries but that the long-run coefficients are equal across countries. However, if equality of the slope coefficients does not hold in practice, this technique yields inconsistent estimators. This assumption is tested using a Hausman test.

For equation (1), adopting the formalization by Blackburne III and Frank (2007), we set-up an initial general autoregressive-distributed lag model AD ($p, q_1, \ldots, q_k$) of the form:

$$\ln(P/c)_{it} = \mu_i + \sum_{j=1}^{p} \lambda_{ij} \ln(P/c)_{i,t-j} + \sum_{j=0}^{q} \beta_{ij}^{'} K_{i,t-j} + \varepsilon_{it} \qquad (2)$$

where number of countries $i = 1, 2, ..., N$; number of periods $t = 1, 2, ..., T$, for sufficiently large T; K_{it} a $k \times 1$ vector of explanatory variables including government expenditure and income variables; and μ_i a country-specific effect.

If the variables in equation (3) are integrated of order one (that is I(1)) and cointegrated, then the error term is an I(0) process for all i. A principle feature of cointegrated variables is their responsiveness to any deviation from the long-run equilibrium. Hence, it is possible to specify an error correction model in which deviations from the long-run equilibrium affect the short-run dynamics of the variables. The error correction equation is formed as:

$$\Delta \ln(P/c)_{it} = \phi_i[\ln(P/c)_{i,t-1} - \zeta_i^{'} K_{it}) + \sum_{j=1}^{p-1} \lambda^{*}_{ij} \Delta \ln(P/c)_{i,t-1} + \sum_{j=0}^{q-1} \beta_{ij}^{'*} \Delta K_{i,t-j} + \mu_i + \varepsilon_{it} \qquad (3)$$

where $\phi_i = -(1 - \sum_{j=1}^{p} \lambda_{ij}), \zeta_i = \sum_{j=0}^{q} \beta_{ij} / (1 - \sum_k \lambda_{ik}), \lambda_{ij}^{*} = -\sum_{m=j+1}^{p} \lambda_{im} \quad j = 1,2,..., p-1$

and $\beta_{ij}^{*} = -\sum_{m=j+1}^{q} \beta_{im} \quad j = 1,2,..., q-1$.

Nonlinearity in the parameters requires that the models are estimated using maximum likelihood.

Another econometric concern for equation (1) is the bias occurring from the potential endogeneity between government spending and pollution, since government spending often increases with pollution because governments implement ecological taxes. Moreover, as already mentioned, the impact of government expenditure may not occur instantaneously. For this reason, we use the lagged share of government expenditure which also may mitigate bias from reverse causality.

3.2 Identifying the short- and long-run effects

Including more than one lags of the government expenditure and income variables in (1) to capture dynamics may result in multicollinearity. Thus, we employ the Koyck transformation of estimating distributed lag models. In particular, we assume that the subsequent effects of government expenditure and income are all of the same sign as their short-run counterparts and that they decline geometrically each year following:

$$\beta_{\kappa t} = \beta_{i0}\, \lambda^{t} \qquad (4)$$

In addition we assume that the speed of adjustment of the pollutants' emissions, to its long-run equilibrium, after a change in government expenditure and income is similar and thus we propose the model:

$$\ln(P/c)_{it} = (\mu_i + \zeta_t)^{*} + \beta_1 \ln Govshare_{it-1} + \beta_2 \ln(GDP/c)_{it} + \beta_3 (\ln(GDP/c))_{it}^{2} +$$
$$+ \beta_4 (\ln(GDP/c))_{it}^{3} + \lambda \ln(P/c)_{it-1} + \theta_{it} \qquad (5)$$

where $\theta_{it} = \varepsilon_{it} - \lambda\, \varepsilon_{it-1}$.

Coefficient β_1 that will be obtained from the estimation of equation (5) can be interpreted as the short-run elasticity of government spending on pollution, while the marginal effect of the income variable can be interpreted as the short-run income elasticity. Long run elasticity of government spending is given by β_1 / (1-λ) while the long-run income elasticity can be obtained by dividing the short-run elasticity of income by the term (1-λ).

4. Results

Before turning to the estimation of per capita pollution equations we should examine the time series properties of the main variables used. Testing for unit roots in panel data requires both the asymptotic behavior of the time-series dimension T, and the cross-section dimension N, to be taken into consideration. Since the panel data set we examine consists of both $N \rightarrow \infty$ and $T \rightarrow \infty$ dimensions, the tests of stationarity performed are based on the Fisher-type Phillips-Peron unit root test. The test allows heterogeneity of the autoregressive parameter and although in its general form does not control for cross-sectional dependence, is more powerful than Levin et al. (2002) in that case[27]. Table 1a presents the results of the Phillips-Perron unit root tests on the variables of interest. There is evidence against stationarity in levels, since in all cases our variables are I(1).

Table 1a: Panel data unit root tests

Variable	no trend c-s means	no trend minus c-s means	with trend c-s means	with trend minus c-s means
	(1)	(2)	(3)	(4)
Log SO_2/c	0.673	0.707	0.316	0.604
Δ(Log SO_2/c)	0.000	0.000	0.000	0.000
Log CO_2/c	0.049	0.361	0.273	0.880
Δ(Log CO_2/c)	0.000	0.000	0.000	0.000
Log Government share lagged	0.224	0.034	0.479	0.043
Δ(Log Government share lagged)	0.000	0.000	0.000	0.000
Log GDP/c	1.000	0.925	1.000	1.000
Δ(Log GDP/c)	0.000	0.000	0.000	0.000
Log GDP/c^2	1.000	0.975	1.000	1.000
Δ(Log GDP/c)^2	0.000	0.000	0.000	0.000
Log GDP/c^3	1.000	0.998	1.000	1.000
Δ(Log GDP/c)^3	0.000	0.000	0.000	0.000

Note: Fisher-type Phillips-Perron unit root tests performed on each panel including zero or one Newey-West lag. All values reported are probabilities. C-s means stands for cross-sectional means.

Additionally, application of the DFE method requires that the variables in the model are cointegrated meaning that there is a long-run relationship among them. Table 1b presents the Pedroni and the Kao (Engle based) cointegration tests for the two pollutants

[27] We also compute the mean of the series across panels and subtract this mean from the series (columns 2 and 4 in Table 1a) to mitigate the impact of cross-sectional dependence.

equations. We reject the null hypothesis of no-cointegration at the conventional statistical significance level of 0.05 in six of the eight cases for the SO_2 equation and in five cases for CO_2. However, in terms of raw power of the statistics for relatively small values of T the rho and panel-v statistics are the most conservative and show a tendency to not reject (Pedroni, 2004), suggesting that evidence of cointegration is even stronger than that depicted in Table 1b.

Table 2 provides the estimates of per capita pollution emissions. In our model, as mentioned, according to the Hausman test FE estimation is preferred to RE. Hence, for each pollutant we report FE and DFE estimates. Dynamics are taken into account in the estimates reported in columns 2 and 4 of the Table. Comparing the MG and PMG estimators, with the use of a Hausman test, we see that the PMG estimator, the efficient estimator under the null hypothesis, is preferred and thus assuming long-run coefficients to be equal across panels is more appropriate in our panel. Additionally, another application of the Hausman test suggests that the simultaneous equation bias between the error term and the lagged dependent variable is minimal in our panel and we may conclude that the DFE model is the most appropriate. In addition, the error correction term in the DFE estimator for both pollutants is statistically significant at the 1% level for both pollutants, suggesting that taking into account dynamics is necessary.

Both pollutants have a significant inverted N-shaped cubic relationship with per capita income in all estimates (for similar findings see for example Cole, 2007). Interestingly, taking into account dynamics in the DFE estimates produces lower turning points for both pollutants. However, the initial turning point is particularly low in all estimates, that essentially for the in sample income observations the estimated EKCs have the conventional quadratic form.

Table 1b: Pedroni residual cointegration test for the two pollution equations

	SO_2/c		CO_2/c	
	Statistic	Probability	Statistic	Probability
Panel v-statistic	4.331	0.000	7.118	0.000
Panel rho-statistic	7.799	1.000	0.181	0.572
Panel PP-statistic	-8.798	0.000	-2.623	0.004
Panel ADF-statistic	-22.60	0.000	-9.173	0.000
Group rho-statistic	12.02	1.000	3.886	0.999
Group PP-statistic	-8.238	0.000	-0.757	0.225
Group ADG-statistic	-25.18	0.000	-9.576	0.000
Kao test (Engle based)	-33.88	0.000	-34.29	0.000

Table 2: Estimates of per capita pollution emissions for the world sample

	SO_2/c		CO_2/c	
	FE	DFE	FE	DFE
Log government share lagged	-0.379**	-0.663**	-0.052	-0.070
	(0.155)	(0.287)	(0.086)	(0.121)
Log GDPc	-27.31**	-22.52	-17.12***	-22.74***
	(11.44)	(13.76)	(4.889)	(7.805)
$(\text{Log GDPc})^2$	3.849**	3.284*	2.269***	2.943***
	(1.444)	(1.716)	(0.586)	(0.914)
$(\text{Log GDPc})^3$	-0.174***	-0.153**	-0.094***	-0.121***
	(0.060)	(0.071)	(0.023)	(0.035)
Constant	57.74*		39.36***	
	(29.67)		(13.29)	
Error correction term		-0.137***		-0.118***
		(0.055)		(0.016)
Turning Points	380/6,673	298/5,502	419/23,242	573/19,228
R^2	0.305		0.392	
F test	0.000		0.000	
Hausman FE v. RE	0.000		0.000	
Hausman MG v. PMG		0.510		0.527
Hausman PMG v. DFE		0.010		0.997
Nobs/Countries	2,190/71	2,119/71	2,698/71	2,627/71

Note: Robust standard errors are in parentheses. All tests' values reported are probabilities.
*Significant at 10%. **Significant at 5% ***Significant at 1%.

On the other hand, a negative direct effect of government share of income on pollution is estimated by all models. Concentrating on DFE estimates the government share of income possesses a negative relationship with SO_2/c which is significant at 5%, but the effect on CO_2/c remains insignificant. In particular, an increase of government expenditure by 1%, ceteris paribus, may result in a 0.663% reduction of SO_2/c emissions, ceteris paribus.

Table 3 presents the estimates of the pollution equations using the Koyck transformation. Results are presented for the whole sample, as well as for two sub-samples, namely the OECD group of countries and one with the rest countries not belonging to the former group. It is interesting to note that the estimated coefficients of the lagged pollutant variables are significant in all cases at the 1% level. In addition, for the SO_2 the coefficient of the lagged pollution variable greatly differs between the two subgroups, suggesting different adjustment rates and rate of return to equilibrium pollution levels after a change in the explanatory variables.

Table 3: Estimates of per capita pollution emissions using Koyck transformation

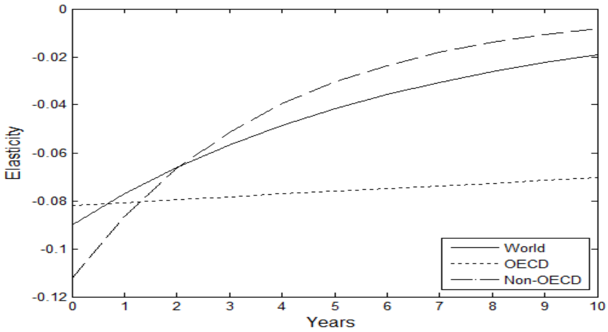
	SO_2/c			CO_2/c		
	World	OECD	Non-OECD	World	OECD	Non-OECD
Log government share lagged	-0.090**	-0.082**	-0.112**	-0.016	-0.023	-0.015
	(0.039)	(0.030)	(0.553)	(0.014)	(0.017)	(0.017)
Log GDPc	-3.569**	-0.084***	1.301*	-2.707**	0.848**	-2.632**
	(1.769)	(0.022)	(0.660)	(1.076)	(7.805)	(1.174)
$(\text{Log GDPc})^2$	0.514**		-0.076*	0.358***	-0.044**	0.345**
	(0.226)		(0.039)	(0.126)	(0.020)	(0.139)
$(\text{Log GDPc})^3$	-0.024**			-0.015***		-0.014**
	(0.014)			(0.005)		(0.005)
Log SO_2/c lagged	0.857***	0.985***	0.771***	0.870***	0.896***	0.864***
	(0.054)	(0.010)	(0.089)	(0.014)	(0.021)	(0.016)
Constant	7.410*	0.913***	-6.386*	6.332**	-3.953**	6.160*
	(4.428)	(0.249)	(3.095)	(2.996)	(1.840)	(3.255)
Turning Points	387/4,103	-	5,215	485/16,751	15,312	412/33,089
Long-run gov. expend. elasticity	-0.629	-5.466	-0.489	-	-	-
Short-run income elasticity	-0.019	-0.084	0.105	0.131	0.006	0.197
Long-run income elasticity	-0.133	-5.600	0.459	1.008	0.058	1.447
R^2	0.821	0.963	0.687	0.878	0.902	0.875
F test	0.000	0.000	0.000	0.000	0.000	0.000
Hausman FE v. RE	0.000	0.032	0.000	0.000	0.000	0.000
Nobs/Countries	2,190/71	828/26	1,362/45	2,698/71	988 /26	1,710/45

Note: Robust standard errors are in parentheses. All tests' values reported are probabilities. Short-run income elasticity, as well as long-run income and government expenditure elasticities are calculated at the sample median level of per capita income of each sub-sample which are $4,565, $14,319 and $2,605 for the World, OECD and Non-OECD groups, respectively. *Significant at 10%. **Significant at 5% ***Significant at 1%.

Consistent with the previous results, the estimated effect of government expenditure is negative in all cases but remains significant only for SO_2. However, the specification of the pollution equation depends on the sample of countries used. In particular, for SO_2, there is evidence for an inverted N-shaped EKC in the full sample and for a quadratic form for the Non-OECD countries; however results suggest a monotonic relationship for the OECD countries. On the other hand, for CO_2 the EKC is inverted N-shaped for the World and Non-OECD countries and inverted U-shaped for the OECD sample.

The estimated long-run elasticities of government expenditure on SO_2 are greater than their short-run counterparts in all cases. The estimated short-run elasticities of government share on SO_2 are of similar magnitude among the different groups, however the same does not hold for the long-run elasticities. The latter are much greater, in absolute value, in OECD countries suggesting that a sustained increase of 1% in government share leads to a long-run reduction of 5.466% in SO_2 emissions, a result which is more than 10 times greater than for Non-OECD countries. This relationship is depicted in Figure 1 where the partial effect of an 1% increase in government expenditure on SO_2 is shown for the following 10 years, for each of the three country groups.

Figure 1: The partial effects of government share on SO2/c



The elasticities of income on SO_2 are negative for the world and OECD countries group but positive in the Non-OECD countries. In particular, the estimate of the long run elasticity of income on SO_2 for the median income OECD country implies that following a 1% sustained increase in income in there will be a 5.6% reduction in SO_2 emissions. On the contrary, a 1% sustained increase in income is estimated to cause a 0.459% increase in SO_2 emissions in a Non-OECD country. For the CO_2 emissions the income elasticities are positive in all samples. However, both in the short- and long-run the effect is much larger in the Non-OECD countries group. Figures 2 and 3 depict these relationships.

Figure 2: Partial effects of income on SO2/c

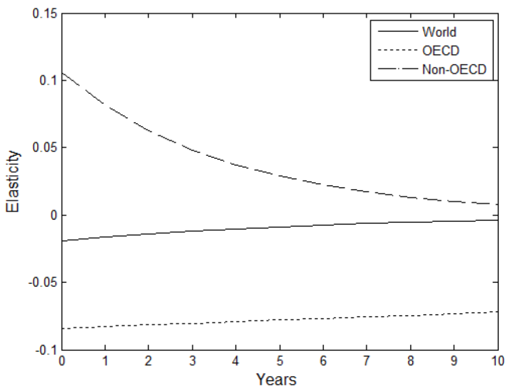
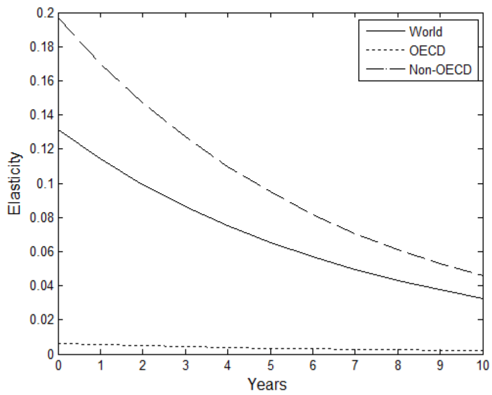


Figure 3: Partial effects of income on CO2/c



4.1 Sensitivity analysis

We test the existence of potential biases from omitted time-variant variables. Table 4 reports the results from estimating the effect of government expenditure under a series of relative correlation restrictions, using the method proposed by Krauth (2011). To account for country fixed-effects, each variable is expressed in terms of deviation from the corresponding country-level average. The results suggest that the estimated effect for SO_2/c is robust, while the same does not hold for CO_2/c, as expected. We find that for the effect on SO_2/c to cease being strictly negative the correlation between government expenditure and unobservables would need to be 6.25 times larger than the correlation with the observables, which seems highly unlikely. However, for CO_2/c a relative correlation of only 40% or greater, implies that the point estimate of the effect includes zero and thus is not strictly negative.

Table 4: Robustness checks for omitted variables bias

Relative correlation restriction (Λ)	Bounds on Government share effect by pollutant $[\theta_L(\Lambda), \theta_H(\Lambda)]$	
	SO_2/c	CO_2/c
{0.00}	-0.363**	-0.025
	(-0.645, -0.081)	(-0.200, 0.151)
[0.00, 0.50]	[-0.457, -0.363]	[-0.025, 0.006]
	(-0.753, -0.110)	(-0.189, 0.193)
[0.00, 1.00]	[-0.554, -0.363]	[-0.025, 0.038]
	(-0.921, -0.119)	(-0.184, 0.271)
[0.00, 5.00]	[-1.634, -0.363]	[-0.025, 0.353]
	(-3.873, -0.120)	(-0.181, 1.430)
[0.00, 10.00]	$(-\infty, \infty)$	$(-\infty, \infty)$
	$(-\infty, \infty)$	$(-\infty, \infty)$
λ	6.25	0.40

Note: Bounds on the effect of government share of GDP on per capita pollution emissions, given relative correlation restrictions. Intervals in square brackets are the bounds themselves, while the intervals in the round brackets are the Imbens-Manski 95% cluster-robust asymptotic confidence intervals.

**Significant at 5%

5. Conclusions

This paper, using a sample of 71 countries for the period 1970-2008 examines the impact of government size and income on pollution taking into account the dynamic nature of the relationships. Our results stress the importance of the long-term effects of a change in income or government expenditure on pollution.

The estimated direct effect of government expenditure is negative and significant for SO_2, but insignificant for CO_2. Estimation of a non-positive direct effect of government size on SO_2 is in line with recent findings by Lopez et al. (2011) and Lopez and Palacios (2010). The results suggest that the direct effect of government spending on pollution is insignificant and considerably smaller for CO_2, in absolute values. This finding comes as no surprise if we take into consideration both pollutants' impact on human health and the technological capabilities of reducing their levels in the atmosphere. In particular, SO_2 emissions externalities are local and immediate while CO_2 emissions externalities are global and occur mostly in the future. Local environmental degradation, as in the case of SO_2, increases demand for technological improvements to diminish that impact. The difference in magnitude and significance between the estimated direct effects of government expenditure on SO_2 and CO_2 could also be explained by how the different types of pollutants respond to certain policies. In particular, the regulation of production generated pollutants, like SO_2, is expected to be more straightforward and this is reflected in the estimated effects.

Policy implications, occurring from the analysis, differ according to the level of income in a country. Many studies have shown that government size reduces prosperity (Folster and Henrekson, 2001; Bergh and Karlsson, 2010). However, cutting government expenditure should be undertaken with particular care in some levels of GDP. Combining our results with those of Halkos and Paizanos (2013), for SO_2 and CO_2 pollution, reducing government size in developing countries leads to deterioration of environmental quality. Therefore, cutting government expenditure in these countries should be accompanied by appropriate environmental regulation along with the establishment of international environmental treaties.

On the other hand, in countries with higher income levels, cutting government expenditures leads to improvements in both income and environmental quality, while these effects may also have a larger long-run effect. These implications bear some resemblance to the EKC. In particular, countries with income level at the decreasing area of the EKC are more likely to have already established the environmental legislation and to have undertaken public expenditures for the improvement of environmental quality, thus they are susceptible to diminishing returns from a further increase in government size. In that context and combining our findings with the results from Lopez et al. (2011), cutting out public spending items that increase market failure will be the most beneficial.

Acknowledgments
This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: Heracleitus II. Investing in knowledge society through the European Social Fund.

European Union
European Social Fund

OPERATIONAL PROGRAMME
EDUCATION AND LIFELONG LEARNING
investing in knowledge society
MINISTRY OF EDUCATION & RELIGIOUS AFFAIRS
MANAGING AUTHORITY

NSRF 2007-2013
programme for development
EUROPEAN SOCIAL FUND

Co- financed by Greece and the European Union

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Οικονομική ανάπτυξη και Περιβάλλον: Ισχύει η υπόθεση της περιβαλλοντικής καμπύλης Kuznets;

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Περίληψη
Η μελέτη αυτή εξετάζει τη σχέση μεταξύ οικονομικής ανάπτυξης και περιβαλλοντικής ζημίας. Εξηγώντας την έννοια της υπόθεσης της περιβαλλοντικής καμπύλης Kuznets η εργασία με τη χρήση κατάλληλων οικονομετρικών μεθόδων ανάλυσης panel δεδομένων εξετάζει εμπειρικά τη σχέση των εκπομπών CO_2/c και του ΑΕΠ/c για ένα σύνολο 32 χωρών και για τη περίοδο 1971-2008. Από τα εμπειρικά αποτελέσματα της ανάλυσης διαπιστώνεται η ύπαρξη μιας Ν-μορφής σχέσης μεταξύ οικονομικής ανάπτυξης και ρύπανσης. Όμως δείχνεται ότι τα εκτιμημένα σημεία καμπής από τα panel δεδομένα μπορεί να μην αντιστοιχούν στα πραγματικά σημεία καμπής που ισχύουν για τις ατομικές χώρες. Συγκεκριμένα για διαφορετικές χώρες σε διαφορετικά γεωγραφικά σημεία βρίσκουμε μια ανάμικτη εικόνα από μονοτονικές ή αντίστροφης U-μορφής ή Ν-μορφής συμπεριφορές. Οι χώρες είναι ετερογενείς με διαφορετικούς στοχαστικούς εκτιμητές παλινδρόμησης. Αυτό συνεπάγεται ότι η χρήση μιας συνολικής Ν-μορφής καμπύλης της σχέσης εισοδήματος-περιβάλλοντος από τους υπεύθυνους λήψης αποφάσεων μπορεί να είναι λανθασμένη και παραπλανητική με σοβαρές συνέπειες αναποτελεσματικότητας των πολιτικών αυτών.

Λέξεις Κλειδιά: Οικονομική ανάπτυξη, περιβαλλοντική ζημία, εκπομπές CO_2, εκπομπές S, ετερογένεια, Panel δεδομένα.

JEL κωδικοί: Q56; O20; C23.

Environment and Economic development: Is the EKC hypothesis valid

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Abstract
In this paper we examine the concept of an Environmental Kuznets Curve (EKC) hypothesis in a critical way aiming to justify its existence as well as to propose policies compatible with sustainable development. For this reason, we make use of a data set on CO_2 emissions for 32 countries over a 36 year time period. For this balanced panel database, we apply a number of econometric methods to estimate the income-environment relationship. Our results indicate the existence of N-shaped relationship between economic development and pollution. However we show that the turning points calculated by panel data analysis

may not reveal the actual turning points valid for individual countries. In our case and using different countries from different geographical regions we found a mixture of monotonic or inverted U-shape or N-shape behaviour. Countries are heterogeneous with different stochastic regression coefficients. This implies that the use of the total N-shape income-environment relationship by policy makers may be misleading with serious policy ineffectiveness implications.

Keywords: Environmental Kuznets Curve; Panel Data; CO_2 emissions.

JEL Classification: Q56, O20, C23.

1. Introduction

The generation of electricity from conventional power stations is associated with a number of environmental problems. For example, generation using coal causes significant air pollution due to emissions of sulphur oxides, carbon dioxide, nitrogen oxides and particulates. In the UK a 2000 MW coal fired station operating at 60% load factor burns about 4.4 million tonnes of coal per year and each year emits into the atmosphere about 10 million tonnes of carbon dioxide, 130,000 tonnes of sulphur dioxide, 40,000 tonnes of nitrogen oxides and between 4,000 and 40,000 tonnes of particulate matter depending on how well the stack emissions are cleared before they are released (Highton and Webb, 1980). Particular concern has been expressed about the emissions of sulphur dioxide because the use of tall stacks to disperse emissions can lead to problems of transnational pollution. Approximately 1 tonne of sulphur burned produces 2 tonnes of sulphur dioxide (SO_2) and sulphur is present, in varying quantities, in both oil and coal.

Kuznets (1955) showed that during the various economic development stages, income disparities first rise and then begin to fall. Degradation tends to be higher in many middle income countries in comparison to less developed countries. The environmental Kuznets curve (hereafter EKC) hypothesis proposes that there is an inverted U-shape relation between environmental degradation and per-capita income. In this paper, we examine the concept of an environmental Kuznets curve in a critical way with an eye towards proposing policies compatible with sustainable development. Environmental damage seems to be lower in the most developed countries compared to many middle-income countries and higher in many middle-income countries compared to less developed countries.

A number of authors have estimated econometrically the EKC using OLS analysis. The EKC estimates for any dependent variable (e.g. SO_2, NO_X, deforestation, etc.) peak at income levels, which are around the world's, mean income per capita. Income as expected is not normally distributed but skewed (with a lot of countries below mean income per capita). Arrow *et al*. (1995), Ekins (1997) and Ansuategi *et al*. (1998) provide a number of reviews and critiques of the EKC studies. Stern *et al.* (1996) identified a number of problems with some of the main EKC estimators and their interpretation. They mention among others the following problems:

a) Econometric problems;
b) The mean-median income problems;
c) The interpretation of particular EKCs in isolation from other environmental problems;
d) The assumption of unidirectional causality from growth to environmental quality and the reversibility of environmental change;
e) The asymptotic behavior

Stern (1998) reviews these problems in details and shows where progress has been made in empirical studies.

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Cropper and Griffiths (1994) and Selten and Song (1994), conclude that the majority of countries in their analyses are below their estimated peak levels for air pollutants and thus economic growth may not reduce air pollution or deforestation. This implies that estimating the left part of EKC is easier than estimating the right hand part. Thus, use of OLS is not likely to yield accurate estimates of the peak levels.

The differences in the extracted relationships as well as in the estimated turning points may be attributed to the econometric models' functional form used and the adoption of static or dynamic analysis. Stern and Common (2001) find that sulfur emissions per capita are a monotonic function of income per capita, when they use a global sample and an inverted U-shape function of income when they use a sample of high-income countries only. They calculate a much larger in size turning point ($ 908178) compared with the total sample, again implying a monotonic EKC. Halkos (2003), using the same database but proposing a dynamic model formulation finds much lower turning points in the range of $2805-$6230 and inverted U-shape curves.

At the same time the inclusion of other independent variables in the model formulation, affects significantly the estimated relationship. Roca et al. (2001) claim that estimated EKC is weaker when more explanatory variables are used together with income. Empirical evidence is not clear and mixed results have been found (Galeotti et al., 2006; He and Richard, 2010; Chuku, 2011).

A number of studies found a linear and monotonic relationship between environmental damage and income per capita. Akbostanci et al. (2009) examined the income–environment relationship in the case of Turkey using time series and provincial panel data for the periods 1968-2003 and 1992-2001 respectively. They found a monotonically increasing relationship between carbon dioxide emissions and income in the case of times series analysis. Similarly, Fodha and Zaghdoud (2010) found a monotonically increasing relationship between CO_2 emissions and GDP for Tunisia and for the period 1961-2004.

Other researchers have found an inverted-U shaped relationship with turning points ranging from \$823 to \$79,000, implying a possible separation of environmental damage from economic development (Grossman and Krueger, 1995; Holtz-Eakin and Selden 1995; Cole et al., 1997; Stern and Common 2001; Halkos, 2003; Galeotti et al., 2006). Fodha and Zaghdoud (2010) found an inverted-U shaped relation with a turning point of \$1,200 for SO2 for Tunisia and the period 1961-2004. Panayotou (1993; 1995; 1997) employed cross sectional data and GDP in nominal US \$ (1985). The equations for the pollutants considered were logarithmic quadratics in income per capita. Deforestation was estimated against a translog function in income/c and population density. All the curves estimated were inverted U's with turning point for deforestation at \$823 per capita. Finally, He and Richard (2010) using parametric, semi-parametric and non-linear models found weak evidence of the EKC hypothesis for the relationship between CO_2 emissions and GDP in the case of Canada and for the period 1948-2004.

Stern *et al.* (1996) claim that the mix of effluent has shifted from sulphur and NO_X to CO_2 and solid waste, in a way that aggregate waste is still high and even if per unit output waste has declined, per capita waste may not have declined. Regressing per capita energy consumption on income and temperature gave them an inverted U-shape relationship between energy and income. Energy consumption peaked at \$14600. The authors claim that the results depend on the income measure used. If income in PPP is used, the coefficient on squared income was positive but small and insignificant. If income per capita was measured using official exchange rates, the fitted energy income relationship was an inverted U-shape with energy use peaking at income \$23900.

Others have found an *N*-shape relationship (Friedl and Getzner, 2003; Martinez-Zarzoso and Bengochea-Marancho, 2004) which shows that the release of environmental damage from economic development may be temporary (He and Richard, 2010). Grossman and Krueger's (1991, 1995) and Shafik and Bandyopadhyay (1992) suggest that at high-income levels, material use increases in a way that the EKC is N-shape. Friedl and Getzner (2003) found an N-shaped relationship between CO_2 and GDP for Australia and for the time period 1960-1999. Akbostanci et al. (2009) found an *N*-shaped relationship in the case of SO_2 and PM10 emissions in their panel data analysis.

A number of alternative theories of the economy-environment relationship exist and are presented in Everett et al. (2010). Namely, the *limits theory* defines the economy-environment relationship in terms of environmental damage hitting a threshold beyond which production is so badly affected that the economy gets smaller. The *new toxics view* relies on the idea that emissions of existing pollutants are decreasing with further economic growth but the new pollutants substituting for them increase. This view questions the existence of turning points and considers the possibility that environmental damage continues to increase as economies grow (Everett et al., 2010). Similarly the *race to bottom theory* states that international competition initially leads to increasing environmental damage, up to the point when developed countries start reducing their environmental impact but also export polluting activities to poorer countries. The net effect, in the best case scenario, is a non-improving situation. Finally, the *Porter's Hypothesis* refers to growth and environment as a false dichotomy and finds that well-designed environmental policy can increase R&D into resource efficient products and processes, resulting in improved business competitiveness and profitability (Everett et al., 2010).

Empirical formulations of the environment-income relationship and the exploration of the EKC hypothesis rely on the econometric specifications that consist of an environmental damage indicator as depending on an economic variable representing economic development like GDP/c in level, square and cubic values as independent variables. Due to lack of data different variables have been used so far in empirical modelling to approximate environmental damage like air pollutants (SO_X, NO_X, CO_2, PM10, CO, etc.), water pollutants (e.g. toxic chemicals discharged in water, etc.) and other environmental indicators (e.g. deforestation, municipal waste, energy use, urban sanitation and access to safe drinking water).

This paper is organised as follows. Section 2 presents the econometric models used in this study. The empirical evidence is presented in section 3. The final section concludes the paper.

2. Econometric methods and Data used

The basic model to be estimated may be written as:

$$Y_{it} = \alpha + X_{it}\beta_{it} + \delta_i + \gamma_t + \varepsilon_{it} \qquad (1)$$

where Y_{it} is the dependent variable; X_{it} is a k-vector of explanatory variables; and ε_{it} are the disturbance terms for i = 1,2,…M cross-sectional units in periods t = 1,2,…T. The parameter α corresponds to the overall constant in the model while δ_i and γ_t represent cross-section and period specific effects (random or fixed) respectively.

Both fixed and random effects are inefficient in the presence of heteroskedasticity (Baltagi, 2001; Hsiao, 1986). In order to take into account heteroskedasticity and various patterns of correlation between the residuals, Generalized Least Squares (GLS) specifications may be used. For estimating β the GLS estimator is given as:

$$\hat{\beta} = (X'\Phi^{-1}\mathrm{X})^{-1}\mathrm{X}'\Phi^{-1}\mathrm{Y} \qquad (2)$$

We have applied panel data methods to estimate the above equation. The first method employed is the fixed effects (hereafter FE) while the second model is the random effects (hereafter RE).

The orthogonality test for the RE and the independent variables is also examined. For this reason, a Hausman test is used in order to test for inconsistency in the RE estimate. In the case of coefficient heterogeneity FE and RE estimates in a static formulation are consistent in the absence of other misspecification (Stern, 2010).

In our case, we analyze CO_2/c emissions in a sample of 32 countries for the period 1971-2006. We have performed Box-Cox tests in order to test the linear against the logarithmic functional form of the relationship between CO_2/c and GDP/c. The model proposed here is estimated as:

$$(CO_2/c)\,it = \alpha_i+\gamma_t+\beta_1(GDP/c)_{it}+\beta_2(GDP/c))_{2it}+\beta_3(GDP/c))_{3it}+\varepsilon_{it} \qquad (4.3)$$

where the α_i's are country specific intercepts and the γ_i's are time specific intercepts and the countries are indexed by i and time periods by t. CO_2/c is carbon dioxide emissions per capita in tons and ε_{it} is a disturbance term. Our sample consists of the 32 countries with full record on CO_2 and GDP per capita information for the period 1971-2006[28]. The database used has 1152 observations per variable. GDP per capita has been used in international prices (2005 US dollars) and the data have been obtained from OECD (2008). The CO_2 data have been obtained from the IEA (2010).

The various econometric specifications lead to different results. Specifically (Halkos, 2013) :

If $\beta_1=\beta_2=\beta_3=0$, there is no relationship between pollution and development

If $\beta_1>0$ and $\beta_2=\beta_3=0$, there is an increasing monotonic or positive linear relationship between pollution and development

If $\beta_1<0$ and $\beta_2=\beta_3=0$, there is a decreasing monotonic or negative linear relationship between pollution and development.

If $\beta_1>0$, $\beta_2<0$ and $\beta_3=0$, there is an inverted U-shape between pollution and development and the EKC I hypothesis is valid.

If $\beta_1<0$, $\beta_2>0$ and $\beta_3=0$, there is a U-shape between pollution and development

If $\beta_1>0$, $\beta_2<0$ and $\beta_3>0$, there ia a N-shape relationship between pollution and development.

If $\beta_1<0$, $\beta_2>0$ and $\beta_3<0$, there is an inverted N-shape relationship between pollution and development.

3. Empirical evidence

Table 1a presents the results of the unit root tests on the variables considered (i.e. CO_2/c and GDP/c). As it can be seen there is evidence against non-stationarity in levels where in all cases our variables are I(1); that is, they are stationary in first differences and non-stationary in levels in all levels of statistical significance. Table 1b presents the Pedroni Cointegration Tests where in seven of the eleven cases we reject the null hypothesis of no cointegration at the conventional statistical significance level of 0.05.

Next, Table 2 presents the panel data model results. Fixed and random effects were estimated first. These models were estimated also with time and country dummies but the

[28] The countries used in our analysis are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland. Italy, Japan, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, UK, USA, Brazil, Chile, China, India, Indonesia, Israel, Russia, South Africa.

results were insignificant. The diagnostic tests for the fixed and random effects models show a number of problems. As the Hausman test shows country intercepts and GDP/c are correlated in the global model. The test shows that the random effects formulation is consistently estimated. This suggests that there are omitted variables, which are correlated with GDP/c. Looking at the Breusch-Pagan Lagrange multiplier test for random effects we reject the null hypothesis in favour of the random effects model and we find significant differences across countries. Similarly, the Pesaran's test of cross sectional independence leads to rejection of the null hypothesis and there is cross-sectional dependence implying the estimation of the Driskoll-Kraay standards errors. Finally the modified Wald test for group-wise heteroskedassticity led to rejection of homoskedasticity.

Table1a: Summary of panel unit root tests

Levels	**Levin, Lin and Chu t***	**Breitung t-stat**	**Im, Pesaran and Shin W-stat**	**ADF- Fiscer Chi square**	**PP- Fiscer chi-square**
CO_2/c	-0.24013 [0.4051]	1.5615 [0.9408]	0.19409 [0.5769]	59.5051 [0.6360]	65.1873 [0.4352]
GDP/c	9.1413 [1.0000]	2.09624 [0.9820]	9.59097 [1.0000]	31.1598 [0.9998]	14.9650 [1.0000]
First Differences	**Levin, Lin and Chu t***	**Breitung t-stat**	**Im, Pesaran and Shin W-stat**	**ADF- Fiscer Chi square**	**PP- Fiscer chi-square**
Δ CO_2/c	-9.06847 [0.0000]	-5.7905 [0.0000]	-13.7486 [0.0000]	304.282 [0.0000]	870.216 [0.0000]
Δ GDP/c	-4.51879. [0.0000]	0.37198 [0.6450]	-6.7141 [0.0000]	162.935 [0.0000]	314.352 [0.0000]

P-values in brackets

Table 1b: Pedroni Residual Cointegration Test

	Statistic	**Prob.**	**Weighted Statistic**	**Prob**
Panel v-Statistic	2.5056	0.0061	-0.5731	0.7170
Panel rho-Statistic	3.4835	0.9908	1.1007	0.8645
Panel PP-Statistic	-1.074	0.8585	-4.039	0.0000
Panel ADF-Statistic	-7.862	0.0000	-4.9215	0.0000
Group rho-Statistic	3.138	0.9991		
Group PP-Statistic	-3.1889	0.0007		
Group ADF-Statistic	-2.914	0.0018		

Source: Halkos (2012)

We have estimated a number of other panel data analysis methods. As we face problem of heteroskedasticity, generalized least squares were estimated with panel specific AR(1) as well as generalized least squares with common AR(1) coefficients for all panels and heteroskedastic panels in both cases. Between the two estimations, the latter performed better. The results are presented in the last column of Table 2. The model passes the diagnostic tests and indicates the presence of an N-shaped curve, and parameter estimates as well as t-statistics are all statistically significant. The turning points are calculated at $22175 and $57231. Although the first is well within the sample the latter is above the maximum value of GDP/c in the sample ($52152).

Table 2: Panel data model estimates

Model	**FE**	**FE Driskoll-Kraay s.e.**	**RE**	**FGLS RE Common AR(1)**
Constant	386.08 (12.243) [0.0000]	386.08 (4.30) [0.0000]	387.95 (2.3253) [0.0202]	177.115 (28.52) [0.0000]
GDPc	0.02174 (2.997) [0.0028]	0.02174 (5.18) [0.0000]	0.0213 (2.943) [0.0033]	0.01793 (58.55) [0.0000]
GDPc2	-1.05E-06 (-2.7697) [0.0057]	-1.05E-06 (-4.72) [0.0000]	-1.03E-06 (-2.7224) [0.0066]	-5.61E-07 (-44.52) [0.0000]
GDPc3	1.78E-11 (3.0458) [0.0024]	1.78E-11 (4.30) [0.0000]	1.76E-11 (3.0091) [0.0027]	4.71E-12 (28.52) [0.0000]
Adjusted R2	0.942	0.942		
Modified Wald test	64000 [0.0000]			
Pesaran test	9.292 [0.0000]			
Breusch-Pagan LM			17010.81 [0.0000]	
Hausman Test			0.74 (P=0.3884)	
Turning Point				22171 and 57235
Heteroskedasticity		1.77 [0.077]	1.47 [0.141]	0.110 [0.91]
Heteroskedasticity		9.76 [0.000]	1.87 [0.062]	0.22 [0.828]
$RESET_1$		4.82 [0.0000]	4.88 [0.0000]	0.81 [0.418]
$RESET_2$		13.39 [0.0000]	13.61 [0.0000]	0.35 [0.7021]

Source: Halkos (2012)

In the same table four more diagnostic tests are presented in the last four rows. The first two are tests for heteroskedasticity while the last two for specification errors. The first test is a regression of the squared residuals on Xs while the second test is essentially a Glejser test. In most cases but the last there is heteroskedasticity problem. The last two tests refer to the specification error and are applied by regressing the residuals on the squared fitted values and on the cubic fitted values. The results of these RESET tests imply that the equations of our model are not misspecified only in the last case.

Moreover, an individual (country) time series analysis has been performed in order to see how much the total extracted relationship (N-shape) represents individual countries. First all the variables of the countries considered were tested for stationarity and were all I(1). Table 3 shows that the picture is unclear. Greece shows N-shape behaviour but at the same time South Africa, Australia and Finland show a monotonic relationship and Brazil an inverted U-shaped relationship. This raises the issue of heterogeneity as discussed analytically in Dijkgraaf and Vollebergh (2005).

Table 3: Individual time series analysis

Model	**Greece**	**South Africa**	**Australia**	**Finland**	**Brazil**
Constant	889.7 (26.98) [0.0000]	151.65 (14.03) [0.0000]	116.37 (39.65) [0.0000]	44.1323 (25.318) [0.0000]	31.94 (3.644) [0.0000]
GDPc	0.0375 (5.261) [0.0000]	0.03812 (9.82) [0.0000]	0.0083 (53.28) [0.0000]	0.00058 (5.928) [0.0000]	0.1014 (11.83) [0.0000]
GDPc2	-2.75E-06 (-6.361) [0.0000]				-1.19E-05 (-7.7575) [0.0000]
GDPc3	4.72E-11 (6.067) [0.0000]				
Adjusted R2	0.93	0.74	0.99	0.51	0.65
Normality	0.38784 [0.8237]	2.175 [0.3371]	0.2825 [0.8683]	0.3031 [0.8585]	1.667 [0.4347]
RESET	0.6573 [0.4175]	0.1557 [0.6931]	0.1956 [0.6583]	0.2531 [0.6363]	1.3579 [0.2439]
ARCH effect	0.131994 [0.7164]	0.2039 [0.9031]	2.0288 [0.1543]	1.999 [0.1617]	1.91292 [0.1516]
Turning Point	8822 and 19240				4261
Comments	N-shaped	Monotonic increase	Monotonic increase	Monotonic Increase	Inverted U-shaped EKC

Figures in parentheses are t statistics and in brackets P-values.
Source: Halkos (2012)

6. Conclusions and Policy Implications

Economic growth leads to higher pollution. This scale effect has several explanations. The demand for environmental quality is higher with higher income levels because of the potential damage irreversibility and higher demand for environmental quality requires stricter environmental regulations (Lieb, 2003). Our results indicate the existence of an N-shaped relationship between economic development and pollution in the form of CO_2 emissions. The N-shape curve has the first turning point at $22171 and the next at $57235. The first is well within the sample while the second is outside the sample size maximum value ($52156). This implies that the reduction of environmental damage from economic development may be temporary and CO_2 emissions will increase indefinitely above the income level of $57235.

We also find that the turning points calculated by panel data analysis may not reveal the actual turning points (if any) that arise for individual countries. In our case and using different countries from different geographical regions we found a mixture of monotonic, or inverted U-shape or N-shape behaviour. This implies that the adaptation of the total N-shape income-environment relationship may be misleading with serious policy ineffectiveness implications.

Lieb (2003) claims that the downturn part of the N-shape may be due to a shock while the upturn part due to an equilibrium relationship. Lieb presents a thoughtful explanation for the final upturn of the extracted N-shape curve. This may be justified by the completion of the internalization of the pollution externality as well as that the abatement opportunities are exhausted. Lieb also claims that there is lower thermodynamics bound on material and energy use per unit of GDP as well as that at higher incomes the control methods applied exhibit decreasing and not anymore increasing returns to scale.

A number of policies may be followed. The need for technology transfer to help developing countries to achieve sustainability emerges. To reduce pollution levels many developing countries expect technology transfers in the form of foreign direct investment from developed countries. These clean and updated technologies will reduce environment damage by controlling emission levels. The main idea is that abatement technologies in developed countries are cleaner and more advanced. As developing countries have no financial resources to import and use these technologies at commercial cost this implies that developed countries should transfer or facilitate the transfer of these technologies to less developed or developing countries. The impact of this technology transfer depends on the type of industrial activity. That is, in the energy sector these transfers will be more beneficial for the environment compared to other industries such as textiles, etc. It should be emphasized that transfer of information must accompany these technology transfers on know-how and skills to enable countries to design or modify their own technologies.

Environmental policy may be a significant initiative for innovation. As air pollution is considered an externality, internalization of this externality requires relatively advanced institutions for collective decision making. This can be achieved only in developed economies.

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Exploring the Energy-Growth link by investigating the E-GDP causal relationship and decoupling estimation: the cases of the USA and China

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Abstract
The complexity of the relationship between energy consumption and economic growth calls for rigorous investigation through different methodological approaches and empirical estimations. The development of contemporary databases, in the context of Material Flow Analysis (MFA), has permitted estimation of the link between economic systems and the energy inputs essential for the production process and CO_2 emissions. Furthermore, the contemporary debate on the causal relationship between energy consumption and economic growth has resulted in numerous econometric studies since the initial seminal paper of Kraft and Kraft in 1978. In this broad context, the present study can be seen as an effort to bridge two different fields of empirical analysis: the energy-GDP causality nexus; and the decoupling effect, for both energy intensity and emissions intensity estimates. Two indicative case studies are investigated: the USA, as a representative post-industrial economy; and China, as a representative highly developing economy. A historical analysis of these two countries, in the light of the empirical evidence on the causal relationship between energy use and GDP growth (the causality investigation) along with energy use intensity per unit of GDP and CO_2 emissions per unit of GDP (estimation of the decoupling effect), contribute to a fruitful comparison among methodologies and results and lay the foundation for an integrated approach to the complex relationship between the use of natural resources and economic growth.

Keywords: Decoupling effect; E-GDP causality; Energy Intensity; Emissions Intensity; Decoupling Index

JEL Classification: O130; Q300; Q320; Q430; Q440.

1. Introduction

The intricate relationship between energy consumption and economic growth, and its implications for both the scarcity of natural resources and global climate change, has long attracted the interest of interdisciplinary scientific research. In the light of this interest, is economic growth in fact making the transition towards lower energy and (energy-related) emissions intensity? Will the transition to a modern service-oriented economy and unparalleled technological progress bring about the decoupling of economic process from energy resources and consequently environmental improvement? There are various ways of scrutinizing these crucial questions. Among the most representative frameworks of empirical analysis for investigating the relationship between energy consumption and economic growth are Energy Intensity (EI) estimation, which concerns the so-called decoupling effect, and the investigation of the causal relationship between energy use and economic growth (the so-called E-GDP causality nexus).

In essence, the former dialogue concerns the empirical estimation of the so-called decoupling of economic growth from the use of natural resources (e.g. energy/material resources) and environmental pressure (e.g. environmental degradation, waste, emissions, etc), while the latter concerns an extensive debate that explores the causal relationship between energy use and economic growth and the effort to determine its direction by employing sophisticated econometric techniques. In this context, the present study could be perceived as a small empirical effort aspiring to cast light on two distinct scientific dialogues concerning the complex relationship between modern economies and energy use. For this purpose, two case studies will be investigated, the USA and China.

2. The Material Flow Analysis (MFA) and the Energy Intensity of the economy

Contemporary empirical studies estimate the Energy Intensity (EI) of economies by means of the methodological principles of economy-wide Material Flow Analysis (MFA). The principal indicator utilized is the Domestic Energy Consumption/Gross Domestic Product (DEC[29]/GDP) ratio, which is among the most cited macroeconomic indicators measuring the decoupling effect (Krausmann et al., 2009; UNEP, 2011). In most case studies, assessment based on MFA ratios seems to verify that EI declines continually. Moreover, a significant number of publications have identified at least a relative[30] decoupling of GDP from energy use over the last 50 years for most of the developed countries and, more recently, for some developing countries as well (Krausmann et al., 2009). Such a trend may raise optimism that modern economic growth is characterized by a transition towards reduced dependency on energy resources.

However, energy requirements - and hence EI - are closely related to the physical dimensions of goods. Goods have certain physical dimensions and therefore "embody" certain amounts of energy flows. We distinguish the most important element, the final receiver of economic goods: human beings. They, as the final consumption unit of human systems, interact with the natural systems which are both the primary source of energy resources and the main sink absorbing wastes, emissions, etc. This crucial interaction between coupled human and natural systems is largely neglected within standard decoupling analyses. In that context, the present study aspires to integrate the socio-demographic dynamics of population growth in a direct and straightforward application within EI estimation. A more detailed analysis of the proposed framework has been published recently (Bithas and Kalimeris, 2013). The present study attempts to estimate the decoupling of economic growth from energy consumption by using both the standard MFA methodology and the alternative framework proposed by Bithas and Kalimeris (2013), in indicative case studies of the USA and China. In addition, it estimates the energy-related

[29] *DEC=domestic energy extraction/production +energy imports – energy exports*

[30] *The relevant literature distinguishes the decoupling effect into two distinct categories: relative decoupling and absolute decoupling. Relative decoupling means that the growth rate of the resource used is lower than the rate of economic growth (GDP), while absolute decoupling is defined as a decline in resource use irrespective of the economic growth rate (UNEP 2011, p. 5)*

CO_2 emissions intensity, that is, the quantity of CO_2 emitted per unit of GDP (and the proposed GDP per capita), in both countries.

3. An insight into the causal relationship between energy and economic growth

The last three decades have seen a growing literature concerning the causal relationship between energy consumption and economic growth. This ongoing debate, starting with Kraft and Kraft's (1978) seminal study, produced at least 172 research papers by 2011, encompassing a wide variety of approaches, econometric methodologies, time periods and proxy variables. In brief, there are four possible findings regarding the direction of the causal relationship between energy consumption and economic growth (Kalimeris et al., 2014):

Neutrality hypothesis or no causality (E≠GDP): This implies that energy consumption is not correlated with GDP growth and it follows that energy scarcity and conservative policies in relation to energy use do not affect economic growth.

Conservation hypothesis (GDP→E): unidirectional causality from GDP growth to energy consumption. This implies that GDP growth causes energy consumption. It suggests that an economy that functions in such a causal relationship is less energy dependent; consequently, conservation policies regarding energy consumption will have little or no adverse effect on economic growth.

Growth hypothesis (E→GDP): unidirectional causality from energy consumption to GDP. This implies that energy consumption causes GDP growth. Consequently, increases in energy consumption may contribute to further economic growth, but reductions in energy consumption may have negative effects on growth.

Feedback hypothesis (E↔GDP): causality between GDP and energy consumption is bi-directional. Energy consumption and GDP growth trigger each other.

The present study limits its scope to reviewing those studies on causality that explicitly concern the USA and China.

4. Data sources

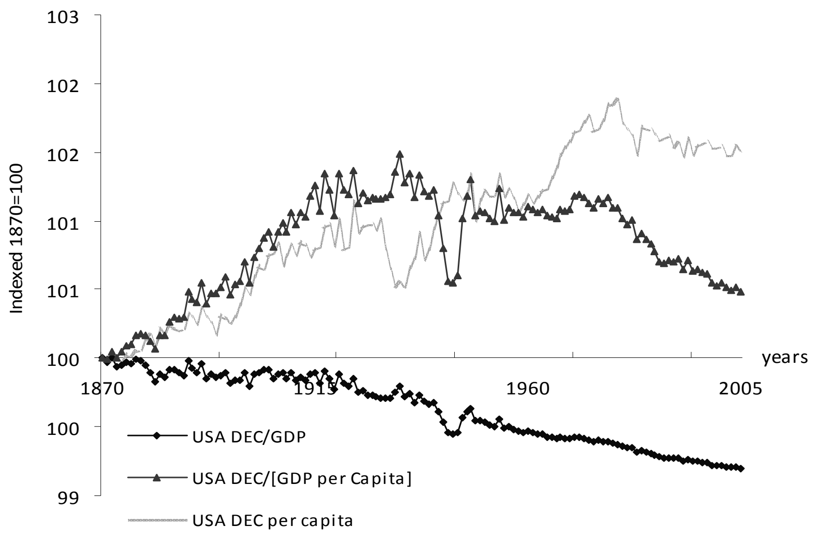
The present study utilized various databases for each level of empirical analysis in the two countries. More specifically, regarding the USA, domestic energy consumption (in PJ) was taken from Gierlinger and Krausmann (2011; *http://www.uni-klu.ac.at/socec/inhalt/1088.htm*), while data on GDP and population were drawn from Maddison (2008; *http://www.ggdc.net/MADDISON/oriindex.htm*). Energy related CO_2 emissions (measured in million tons) for USA were derived from the "Earth Policy Institute" data center (*http://www.earth-policy.org/data_center/C23*). In the case of China, data on primary energy consumption (in mtoe) and energy related CO_2 emissions were obtained from BP's "Statistical Review of World Energy 2013"(*http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy-2013/review-by-energy-type.html*). Data on GDP and population were drawn from the conference board "The Total Economy Database" (*https://www.conference-board.org/data/economydatabase/*). GDP is expressed in both case studies in million 1990 International Geary-Khamis dollars[31] per year (million 1990 GK$/y). Population is in millions. Lastly, in order to review E-GDP causality we took data from a recently published meta-analysis of the literature (Kalimeris et al., 2014).

5. The case of USA

5.1 Estimating the US Energy Intensity for 1870-2005

This section aims to cast light on energy consumption trends in the US economy, which is among the most representative highly developed post-industrial economies. The USA is simultaneously the world's largest energy consumer[32] and largest economy. Figure 1 presents the EI for the USA, estimated by both standard DEC/GDP and the alternative DEC/[GDP $_{\text{per Capita}}$] proposed by Bithas and Kalimeris (2013), and the USA DEC per capita consumption, for 1870-2005. All are indexed (1870=100).

Figure 1. USA Energy Intensity and DEC $_{\text{per capita}}$, for 1870-2005



The DEC/GDP ratio, which initially indicates a relatively stable EI (1870-1923), shows a continual EI decrease (decoupling) from 1924 until 2005. On the other hand, the proposed DEC/[GDP $_{\text{per Capita}}$] shows EI increasing continually during 1870-1933, indicative of a coupling trend. After 1934, with the exception of strong decoupling during WWII, relative stability holds until 1977. Finally, the DEC/[GDP $_{\text{per Capita}}$] ratio decreases throughout 1978-2005. Special note should be taken of the DMC $_{\text{per capita}}$ trend which decreases in 1979-1983 and remains relatively stable in 1985-2005.

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[31] 1990 international Geary-Khamis dollars are purchasing power parities (PPPs) used in evaluating output. They are calculated based on a specific method devised to define international prices.

[32] At least in the period examined here (until 2005). However, after 2009, China takes the lion's share of total Primary Energy Consumption, although the US economy remains the world's largest economy by 2012 GDP according to the World Bank's databases.

5.2 Estimating the USA Decoupling Index for 1870-2005

Estimating the EI alone has limited ability to measure the magnitude of the decoupling effect precisely. In order to verify whether the observed decoupling is relative or absolute, a second level of analysis is essential: the estimation of the Decoupling Index, proposed by UNEP (2011). In order to smooth out short-term fluctuations of the economic cycles, we estimate a time period of one decade, instead of the proposed one-year period, by using moving averages.

First, we estimate the DI using the US DEC/GDP ratio:

$$DI = \frac{(DEC_t - DEC_{t-1})/DEC_{t-1}}{(GDP_t - GDP_{t-1})/GDP_{t-1}} = \frac{\Delta(DEC)}{\Delta(GDP)} \qquad (1)$$

where t is an averaged time period of one decade. Hence, *t-1* represents the change from the average of one decade to the next. Second, we estimate the DI for US DEC/[GDP $_{\text{per Capita}}$], using the same formula but with GDP replaced by GDP per Capita throughout. UNEP (2011) proposes the following interpretation for DI:

When DI>1, no decoupling is taking place.

DI=1 is the turning point between absolute coupling and relative decoupling.

When 0<DI<1, relative decoupling is taking place.

DI=0 implies that the economy is growing while resource consumption remains constant. This is the turning point between relative and absolute decoupling.

When DI<0, the relationship can be described as absolute decoupling.

Figure 2. USA Decoupling Index for DEC/GDP and DEC/[GDPpc] for 1870-2005

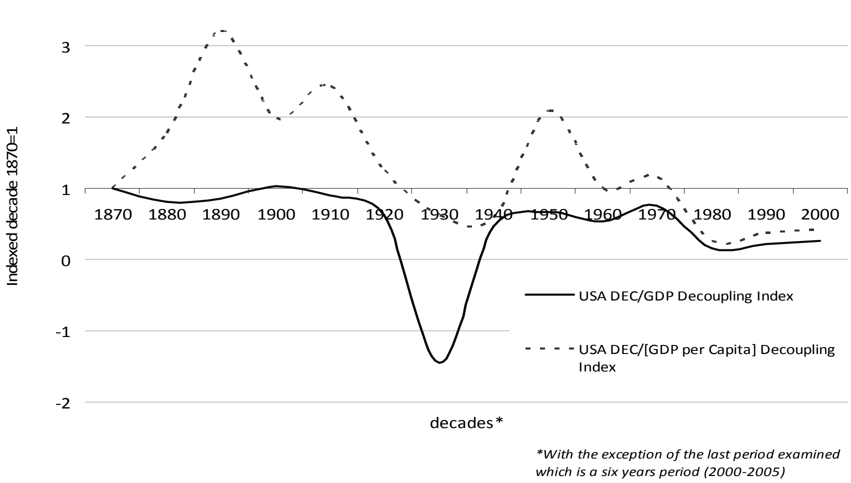
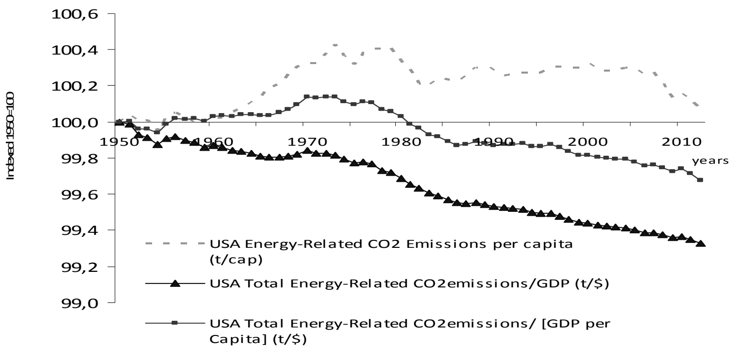


Figure 2 shows estimated DI for both the DEC/GDP and DEC/[GDP $_{\text{per Capita}}$] ratios for 1870-2005. The former presents a relative decoupling trend except in the decade of the 1900s. Furthermore, 1920-1940 is a period of absolute decoupling (DI<0). In contrast, the proposed DEC/[GDP $_{\text{per Capita}}$] indicates two periods of coupling (1870-1930; 1940-1970) and two periods of relative decoupling (1930-1940; 1970-2000). From the 1980s, both indicators present a similar picture of DI (relative decoupling).

5.3 Estimating USA CO_2 emissions intensity for 1950-2012

Figure 3 presents estimates of the USA energy-related CO_2 emissions intensity in both the standard and the proposed frameworks. In addition, it shows the energy-related CO_2 emissions per capita. While the emissions per unit of GDP show a continuous declining trend (excluding two short periods of stability in the mid-1950s and early 1970s), the emissions per unit of GDP per capita increase during 1950-1970 and decrease after 1980. Furthermore, the emissions per unit of GDP per capita stabilize during 1986-1996, decreasing again after the late 1990s. On the other hand, emissions per capita seem to peak in the early 1980s, remain relatively steady during 1980-2005 and decrease strongly during 2006-2012.

Figure 3. USA Carbon Dioxide Emissions Intensity for 1950-2012



5.4 The case of the USA in the E-GDP causal relationship dialogue

Table 1: Review of studies on the causal relationship between E and GDP for the USA

Author(s)	Year	Time period	Causality conclusion
Kraft and Kraft	1978	1947-1974	E←GDP
Akarca and Long	1980	1950-1970	E≠GDP
Yu and Hwang	1984	1947-1979	E≠GDP
Abosedra and Baghestani	1989	1947-1987	GNP→E
Yu and Jin	1992	1974-1990	E≠GDP
Stern	1993	1947-1990	E→GNP
Cheng	1996	1947-1990	E≠GDP
Zarnikau	1997	1970-1992	E↔GNP
Stern	2000	1947-1994	E→GNP
Thoma	2004	1970-2000	E→income
Soytas et al.	2007	1960-2000	E≠GDP
Bowden and Payne	2009	1949-2006	E→GDP generally
Payne	2009	1949-2006	Renew≠GDP Non Ren≠GDP
Warr and Ayres	2010	1946-2000	EX→GDP
Payne and Taylor	2010	1957-2006	Nuclear≠GDP
Payne[a]	2011	1949-2006	Coal≠GDP GDP→Gas Petroleum→GDP
Payne[b]	2011	1949-2007	BioE→GDP
Fallahi	2011	1960–2005	Different Regimes

Table 1 lists those contributions to the causality debate that explicitly investigate the case of the USA, specifically, 18 studies during 1978-2011. Seven (38.9%) studies support the neutrality hypothesis (E≠GDP); six (33.3%) support the growth hypothesis (E→GDP), including one (Thoma, 2004) that explicitly examines the causality between E and Income (GDP per capita); two studies (11.1%) support the conservation hypothesis (GDP→E); and only one study (5.6%) supports the bidirectional hypothesis (E↔GDP). Payne (2011) gives mixed results for different energy resources and Fallahi (2011) examines different time regimes, giving different causality results per regime.

6. The case of China

6.1 Estimating the Chinese Energy Intensity for 1965-2012

This section investigates EI in China, the most representative highly-developing country of the world. Figure 4a presents the total and the per capita primary energy consumption for China for 1965-2012, both indexed (1965=100). The year 2002 is a milestone that signals a dramatic increase in both ratios, lasting until 2012. Evidently, the Chinese economy has been consuming massive amounts of energy in the last decade. On the other hand, Fig. 4b presents estimates of both the standard and the proposed EI indicators (indexed 1965=100). Both reveal a steep coupling trend until 1978, followed by a fluctuating reduction in EI during 1979-2002. Finally, EI trends stabilize from 2002 up to 2012; this too is depicted by both indicators. During 2002-2012, the period of extreme increase in primary energy consumption, the EI seems to be stable for both indicators, with the proposed EI indicator hinting at a smooth EI increase from 2009.

Figure 4a. China Primary Energy Consumption and per capita Primary Energy Consumption indexed (1965=100) for 1965-2012

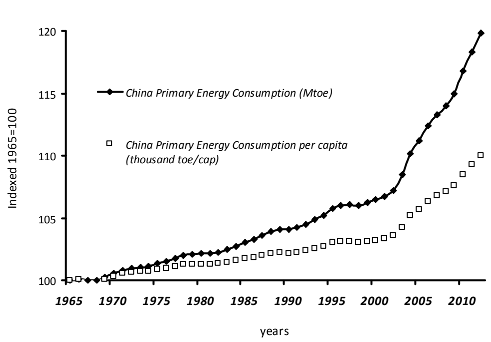
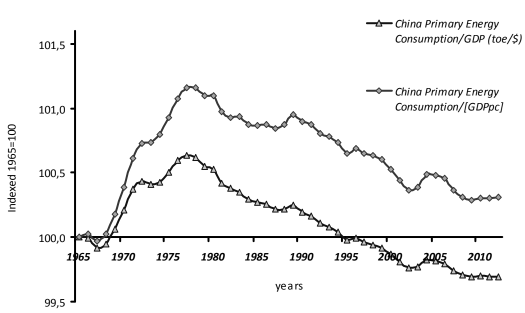


Figure 4b. China Primary Energy Intensity (indexed 1965=100) for 1965-2012

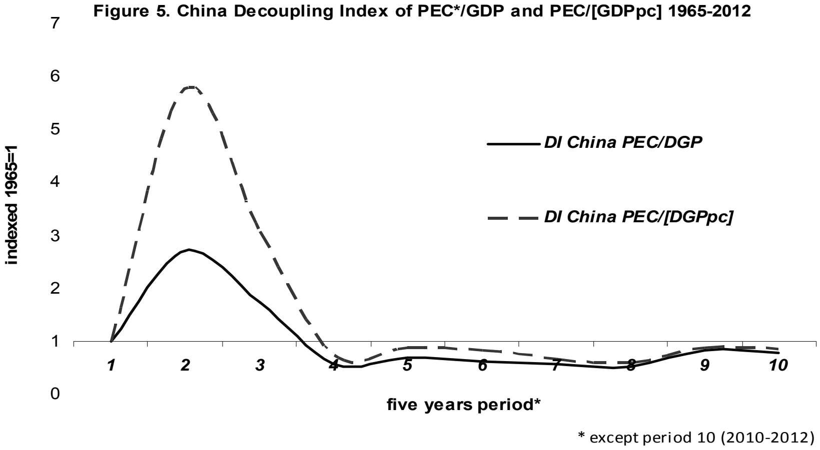


6.2 Estimating the Chinese Decoupling Index for 1965-2012

Figure 5 presents estimates of the Decoupling Index for China. For more details about the interpretation and the methodology used for its construction, see Section 5.2. Time periods on the horizontal axis are five-year periods, (period 1=1965-1969; period 2=1970-1974, and so on), and moving averages are employed. Both the standard and the proposed indicators demonstrate an extreme coupling trend during 1965-1979.

Subsequently, in 1980-2004, both show relative decoupling (DI<1). However, values in the last two periods (2005-2012) are very close to one (DI≈0.85 for both indicators), which represents the borderline between relative decoupling and no-decoupling.

Figure 5. China Decoupling Index of PEC*/GDP and PEC/[GDPpc] 1965-2012



6.3 Estimating the Chinese CO_2 emissions intensity for 1965-2012

Figure 6a shows the Chinese energy-related CO_2 emissions intensity for both the indexed (1965=100) standard and the proposed indicators, for 1965-2012. Figure 6b depicts per capita energy-related CO_2 emissions for the same period (1965=100). Figures 6a and 6b present remarkable similarities with Fig. 4a and 4b, respectively.

Figure 6a. China Carbon Dioxide Emissions Intensity for 1965-2012

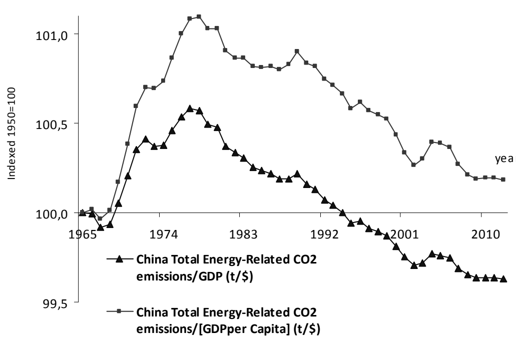
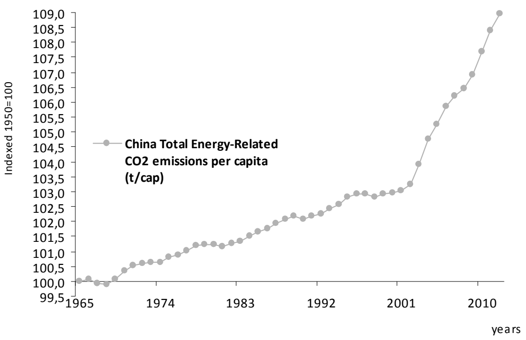


Figure 6b. China Carbon Dioxide Emissions per capita for 1965-2012



6.4 The case of China in the E-GDP causal relationship dialogue

Table 2 lists the contributions to the causality debate that explicitly investigate the case of China. Of the ten recent studies (all after 2004), four (40 %) support the growth hypothesis (E→GDP), two of which concern only electricity consumption (Shiu and Lam, 2004; Yuan et al., 2007) while one estimates the energy intensity causality on economic structure[33] (Feng et al., 2009). The bidirectional hypothesis (E↔GDP) is supported by three studies (30%), and the conservation (GDP→E) and neutrality hypotheses (E≠GDP) find support in one study each. Finally, there is one study with mixed results (Yanqin, 2011).

[33] *Economic structure is defined as the percentage of added value by tertiary industry in GDP*

Table 2: Review of studies on causal relationship between E and GDP for China

Author(s)	Year	Time period	Causality conclusion
Shiu and Lam	2004	1971-2000	Electricity→GDP
Soytas and Sari	2006	1971-2002	E≠GDP
Zou and Chau	2006	1953-2002	Oil Cons.↔GDP
Yuan et al.	2007	1978-2004	Electricity→GDP
Yuan et al.	2008	1963-2005	E↔GDP
Zhang and Cheng	2009	1960-2007	GDP→E
Feng et al.	2009	1980-2006	Energy intensity→ Economic Structure
Yanqin	2011	1980-2008	Varied
Yin and Wang	2011	1953-2008	E→GDP
Shuyun and Donghu	2011	1985–2007	E↔GDP

7. Conclusions

The present paper aims to address the intricate relationship between energy resources, energy-related emissions and economic growth, employing two different methodological approaches. Towards this end, the study has performed a three-level analysis for the two indicative cases of USA and China: first, it estimates the EI and the energy-related CO_2 emissions intensity, using both the mainstream and an alternative methodological framework; second, it estimates the so-called Decoupling Index (DI), in order to classify the observed decoupling trends into relative and absolute (or no) decoupling; third, it reviews and classifies those studies of the so-called E-GDP causality dialogue that explicitly concern the USA and China. The main purpose of this review is to trace and to evaluate the possible implications and interrelations that the causality debate might have with the decoupling effect and the EI trends for these two countries.

Differences have been revealed in EI estimated by the standard and the proposed EI indicators, especially in the case of the USA. Furthermore, the emissions intensity presents similar trends with the EI; the USA presents continuous decline in energy and emissions intensity throughout recent economic history, whereas China shows stabilization in both in the last few years. Concerning the causality debate, it seems that the neutrality hypothesis is the prevailing result for USA, followed closely by the growth hypothesis, so there is no clear evidence concerning the actual direction of causality for USA. What is more, the neutrality hypothesis is not verified by the proposed EI indicator which reveals substantial periods of coupling between energy use and economic growth. In the case of China, the growth hypothesis seems to be the prevailing causality result, while EI and emissions intensity seem to remain constant in recent years (2007-2012). In any case, this targeted partial review of the causality debate reflects, to some extend, the shortcomings of the entire causality debate, which have led to severe recent criticism for inconsistency and mixed results (Kalimeris et al., 2014).

Finally, future research could benefit from applying and integrating other levels of analysis within the present one, such as the addition of the Environmental Kuznets Curves (EKCs) empirical estimates, the Physical Trade Balance (PTB) among countries, and the rigorous estimation and evaluation of the magnitude of the possible effect of outsourcing on declining trends of EI in developed countries. In that sense, an effort to integrate the conclusions of various methodologies might prove to be a fruitful enhancement of the dialogue and cast more light on the complex relationship between energy and development. The present study can be seen as a small contribution in this direction.

Acknowledgements
The present research was co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program “Heracleitus II: Investing in the knowledge society”

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Ερμηνευτικοί παράγοντες της μεταβολής των εκπομπών CO_2 στην Ευρωπαϊκή Ένωση πριν και μετά την οικονομική κρίση

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Περίληψη
Η Ευρωπαϊκή Ένωση κατέχει σταθερά μία ηγετική θέση στην παγκόσμια προσπάθεια καταπολέμησης της κλιματικής μεταβολής, ενώ στο σύνολο της υπερκάλυψε το στόχο του Κιότο για τη μείωση των εκπομπών αερίων του θερμοκηπίου. Στο επίπεδο των κρατών-μελών όμως, παρατηρείται μία αισθητή διαφοροποίηση των επιδόσεων. Στην εργασία αυτή διερευνώνται οι προσδιοριστικοί παράγοντες που ερμηνεύουν τη μεταβολή των εκπομπών CO_2, του πιο σημαντικού αερίου του θερμοκηπίου, κάθε κράτους μέλους της ΕΕ με στόχο να αναδειχθεί ο βαθμός αποσύνδεσης της οικονομικής μεγέθυνσης από το ύψος των εκπομπών, αλλά και η σχετική συμβολή παραμέτρων που σχετίζονται με διαρθρωτικές και τεχνολογικές μεταβολές της οικονομίας τους. Τα αποτελέσματα αναδεικνύουν μία σημαντική αναστροφή της συμβολής των διαφόρων ερμηνευτικών παραμέτρων στην περίοδο μετά την οικονομική κρίση, υποδηλώνοντας μία παράπλευρη αρνητική επίπτωση της ύφεσης στην αποτελεσματικότητα χρήσης των πόρων και κατ' επέκταση στο περιβάλλον. Η μεθοδολογία που εφαρμόζεται είναι η ανάλυση αποδόμησης (decomposition analysis) και ειδικότερα η μέθοδος με χρήση δεικτών, Log-Mean Divisia Index I.

Λέξεις Κλειδιά: Εκπομπές CO_2, Ευρωπαϊκή Ένωση, χρήση δεικτών, οικονομική κρίση.
JEL Κωδικοί: O44; O47; O52; Q43; Q56.

Drivers of carbon emissions in EU countries before and during the economic crisis

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Abstract
The present paper is addressing the challenge faced by European Union (EU) to achieve a sustainable low carbon economy and in particular, to reduce carbon emissions by 20% up to 2020, according to the targets set in its “energy and climate package”. A decomposition analysis is performed in each EU country in order to uncover the explanatory factors behind the changes in CO_2 emissions, during the period 2000-2010 and to detect major drivers and common trends. The period under investigation was split into two time intervals, before and

during the economic crisis in order to more accurately identify the respective effects of the examined drivers. The decomposition approach used relies on the Log Mean Divisia Index I method. It was found that during the period of economic growth, rising emissions have been offset by significant improvements in energy intensity, denoting a more efficient use of energy resources due to technological and organizational changes. The fuel mix in the economy and in the electricity generation sector seems to play a minor role to emission reduction. The picture is quite different during the economic recession, with energy intensity effect becoming less apparent or even contributing to emissions rise, while changes in the fuel mix appear as the major driver to emission reduction. Finally, structural changes had a limited effect in both periods, although the shift toward the service sector appears to contribute to emission reduction, especially in the most developed EU countries.

Keywords: Carbon emissions; decomposition analysis; growth, energy; European Union.
JEL Classification: O44; O47; O52; Q43; Q56.

1. Introduction

The European Union (EU) is steadily at the forefront of the fight against climate change. Following early actions aiming at the deployment of Renewable Energy Sources (RES) and the efficient use of energy, the EU played a leading role for undertaking global actions against climate change under the Kyoto Protocol. Moreover, in 2007 the EU set ambitious targets for 2020: to cut CO_2 emissions by 20% of 1990 levels, to increase the share of RES to 20% of total energy consumption and to reduce energy consumption by 20% of its projected 2020 levels (COM, 2007).

In order for CO_2 emission reduction targets to be successfully achieved by 2020, it is very important to look back in the past. Specifically, discovering the reasons explaining any progress or delay in the evolution of CO_2 emissions can offer valuable information in the design and/or adaptation of effective policy measures. In fact, the different point of departure, and the different efforts undertaken by each country have significantly influenced emission reduction (Diakoulaki and Mandaraka, 2007). Moreover, the financial crisis that hit the world economy in 2008-09, may also affect the mix of measures adopted by each country.

Decomposition analysis is widely recognized as a powerful tool for detecting the driving forces behind changes of various aggregate indicators over time. Relevant methods have been widely used in energy studies since the early eighties, as a response to the preceding energy crisis. The growing concern for climate change has gradually shifted the focus of research to the carbon emissions arising from energy production and use, thus providing a more integrated assessment of countries and sectors with respect to sustainability. An early literature review conducted by Ang and Zhang (2000) found a total of 124 studies using a Decomposition methodology for energy and environmental analysis. Since then, the number of studies has shown an exponential growth (Xu and Ang, 2013). Relevant studies are conducted either at country level or focus on specific sectors, notably on industry, transport, electricity generation and the building sector.

In this paper we examine the evolution of carbon emissions during the period 2000-2010 in 25 out of the 27 EU countries (excluding Luxemburg and Malta), as well as for the average of EU-27. The period under investigation was split into two time intervals, before and during the economic crisis in order to more accurately detect the effect of economic crisis on emission reduction. European economies are divided into 6 main economic sectors according to NACE Rev.2), namely: A: Agriculture, fishing. B: Mining and quarrying. C: Manufacturing. D-E: Electricity, gas and water supply. F: Construction. G-U: Services

The remainder of this paper is structured as follows: Section 2, presents the methodological approach, the examined driving forces and the developed decomposition models. Section 3 gives some background information about the trends of CO_2 emissions and their major driving forces at the EU-27 level. In Section 4 the obtained results are presented and discussed, while some concluding remarks are included in Section 5.

2. Decomposition Analysis

Decomposition methods can be divided into two broad categories, namely Index Decomposition Analysis (IDA) and Structural Decomposition Analysis (SDA). The former relies on the use of indicators drawn usually from statistical databases and are the most commonly use methods in energy and emissions analyses. The principal advantages of IDA methods are their flexibility and data availability facilitating time-series analysis and cross-country comparisons. On the other side, SDA exploits the greater detail offered by I-O Tables to perform a deeper investigation of sectoral interlinkages within economic systems (Hoekstra and Van der Bergh, 2003; Su and Ang, 2012).

The present paper is using one of the most widespread IDA methods, the Log Mean Divisia Index method I (LMDI I) that was first introduced by Ang and Liu (2001). In addition to its easy formulation combined with a robust theoretical foundation, other advantages of LMDI I are (Ang, 2004; 2005): (a) the provision of complete results without residual terms, (b) the fulfillment of the time reversal test, e.g. variations estimated between periods 0 to *t*, and vice versa, are equal in absolute terms and (c) the effective handling of zero values. We are using the additive LMDI I, which facilitates the presentation of results in the familiar and easily comprehensible percentage form.

Namely, for an indicator V defined by means of n factors, x_1, x_2,…, x_n, and assuming that for the period [0-t] its value changes from $V^0= x_1^0 x_2^0 \ldots x_n^0$ to $V^t= x_1^t x_2^t \ldots x_n^t$, this change is decomposed as follows:

$$\Delta V = V^t - V^0 = \Delta V_{x_1} + \Delta V_{x_2} + \cdots + \Delta V_{x_n} \tag{1}$$

According to the additive LMDI I, the effect of the determinant factor x in Eq. (1) is given by:

$$\Delta V_x = \sum_i \sum \left(L\left(V_{ij}^t, V_{ij}^0\right) \cdot \ln\left(X^t / X^0\right)\right) \tag{2}$$

where ΔV_x is the change in the aggregate caused by each determinant factor x and $L(V_{ij}^t, V_{ij}^0)$ is the weight function as defined in Ang, 2004:

$$L\left(V_{ij}^t, V_{ij}^0\right) = \left(V_{ij}^t - V_{ij}^0\right) / \left(\ln V_{ij}^t - \ln V_{ij}^0\right) \tag{3}$$

In our analysis we distinguish the following main drivers of CO_2 emissions:

Output effect: Economic growth is certainly the most straightforward driver, since changes in the level of production output are directly pulling emissions in the same direction. Moreover, it is clear that economic growth is an overarching goal for all countries and that the challenge is to combine growth with fewer emissions.
Thus, in periods of economic growth, all other drivers reflect changes that take place as a result of spontaneous or policy oriented transformations at the economic, technological and social level. The most important among these drivers that may enhance or counterbalance emissions are:
Structural effect: The composition of the economic output is expected to influence emissions, depending on the particular characteristics of each sector and specifically its energy intensity. Thus, an increasing share of energy intensive sectors may push up emissions, whereas shifts towards services are expected to reduce them.
Intensity effect: The intensity of using production factors -typically defined as the inverse of resource productivity- reflects technological and organizational progress which is also highly influencing the level of emissions. Thus, increasing energy productivity (or energy efficiency) is expected to reduce emissions. Of course, relevant positive and negative effects are more pronounced in energy -intensive sectors.
Mix effect: Different fuels and forms of energy contribute to carbon emissions to a different extent, because of their different carbon content, while possibly also influencing energy efficiency as they rely on different technologies.
Utility effect: Although the use of electricity in final demand sectors does not produce any emissions, electricity is associated with carbon emissions depending on the energy mix used in the generation process. Thus, the penetration of RES in the electricity sector is expected to reduce the average emission factor attributed to electricity and the overall amount of CO_2 emissions in the country.
Based on the above factors, CO_2 emissions, can be defined according to formula (4):

$$C_t = \sum_{ij} C_{ij} = \sum_{ij} P \cdot \frac{P_i}{P} \cdot \frac{E_i}{P_i} \cdot \frac{E_{ij}}{E_i} \cdot \frac{C_j}{E_{ij}} = P \cdot \sum_{ij} a_i \cdot e_i \cdot s_{ij} \cdot f_j \qquad (4)$$

Where,
P is the output of the total economy, measured by the Gross Domestic Product (GDP) in constant 2005 prices,
$\boldsymbol{\alpha_i}$ is the share of the Value Added (P_i) of sector i in total output, P.
$\mathbf{e_i}$ is the energy intensity of sector i, expressed by the ratio of energy consumption in the sector i (E_i) to its output, P_i.
sij is the share of fuel j in total energy consumption of sector i, E_i,
fj is the carbon emission factor of fuel j.
Hence, the total change over a time period [0-t], ΔC_{t-0}, is expressed as the sum of the changes due to the following determinant factors:
the output effect (ΔP),
the structural effect ($\Delta \alpha$),
the energy intensity effect (Δe),
the fuel mix effect (Δs), and
the utility effect (Δf).

$$\Delta C_{t-0} = C_t - C_0 = \Delta P_{t-0} + \Delta a_{t-0} + \Delta e_{t-0} + \Delta s_{t-0} + \Delta f_{t-0} \quad (5)$$

Data on GDP and sectoral Value Added, as well as on energy consumption, fuel and electricity mix at the sector and country level were collected from the Eurostat database.

3. Carbon emissions and their drivers in EU-27

Changes in the level of carbon emissions in EU-27 together with the trends of their key drivers provides a first snapshot of the forces enhancing or delaying the processes towards a sustainable economy. Although, significant differences exist among EU Member States, the following facts and figures help understanding the results of the decomposition analysis and the reasons of any deviations.

The first years of the 21st century have been marked by a rapid growth of the European economy, which lasted until 2007, followed by a period of recession that is still present in many countries. Fig. 1 shows for EU-27, the evolution of GDP and CO_2 emissions, in relative terms. It can be seen that the EU as a whole has achieved to disentangle economic growth from carbon emissions as a result of its continuous efforts to combat climate change. It should be noted that EU has over-achieved its Kyoto commitment, and is expected to successfully meet the target for 2020 of cutting CO_2 emissions to 20% below 1990 levels.

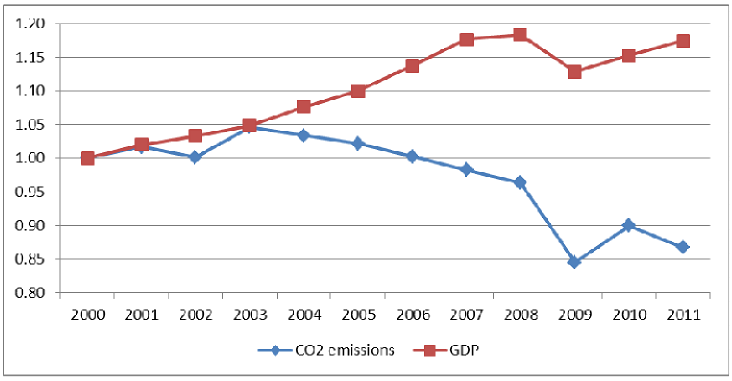

Figure 1:. Relative evolution of GDP and CO_2 emissions in EU-27.

There are clearly certain broad patterns of structural changes that are quite similar across the Member States of the EU. As a result of globalization, economies turn to new forms of competition, the international trade increases and new markets emerge. In these circumstances, there are an increasing number of businesses relocating part or the whole of their activities to other countries, offering lower costs, more favourable legislation and better access to markets. In addition, many EU countries seem to move up the value chain by adopting innovative production processes and increasingly shifting towards services. Fig. 2, shows the considerable expansion in broad service sectors recorded in EU 27.

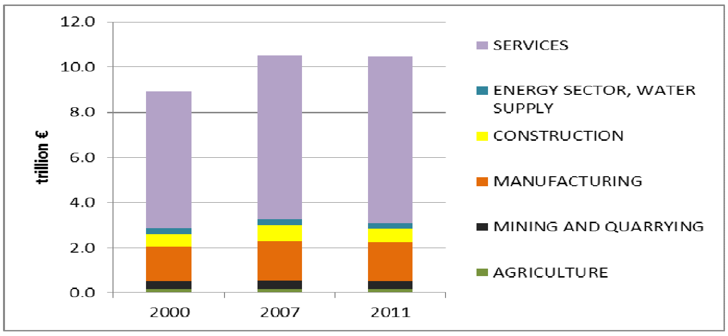

Figure 2: The distribution of GDP to major economic sectors in EU-27.

There are several signals of remarkable improvements in resources productivity. Fig. 3 shows in relative terms that energy intensity has decreased by 15% during the decade 2000-2010, denoting a significant improvement in the productivity of energy resources due to technological progress and organizational reforms. It can also be seen that the financial crisis seems to have negatively affected this progress.

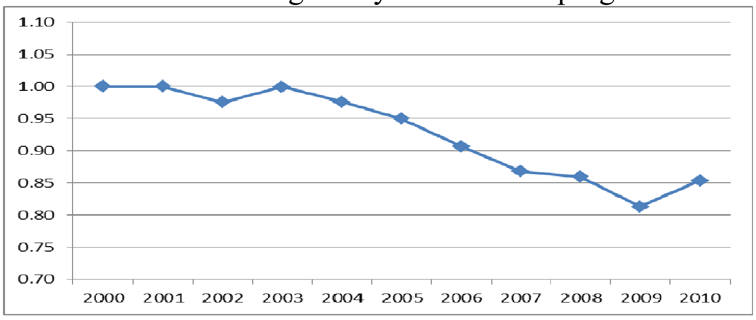

Figure 3: Relative evolution of energy intensity in EU-27.

Finally, the energy mix used in the economy and the electricity generation sector, shows also a notable shift towards cleaner energy forms. As shown in Fig. 4, the corresponding weighted average emission factors are steadily decreasing after 2003, mainly because of the rapid deployment of RES in electricity generation and the uptake of (cleaner) electricity and natural gas in total energy mix.

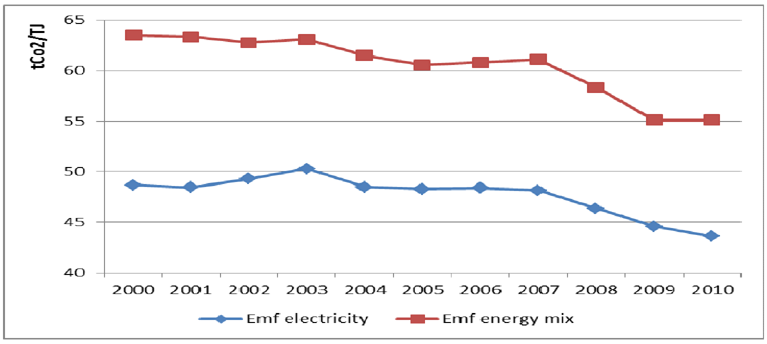

Figure 4: Weighted average emission factors (Emf) of electricity and energy mix in EU-27.

4. The results of the Decomposition Analysis

By implementing the model described in section 2, the change in CO_2 emissions in each of the 25 EU countries and in EU-27, has been decomposed in its underlying driving factors. The analysis has been performed for two distinct periods, namely 2000-2007 and 2007-2010 in order to detect any reversals due to economic recession (Fig. 5 and Fig. 6). The order of countries in the subsequent figures follows the overall performance with respect to the overall change in CO_2 emissions.

It can be seen that during the first period, 10 out of the 25 countries have significantly increased their CO_2 emissions (especially countries in transition and countries with a positive Kyoto target, like ES, EL, IE), whereas in the second period there were only 5 countries that increased their emissions, though to a much lower degree. Furthermore, the range of performances in total emission changes is much larger in the first period (±40%), and is reduced from +15% to -25%, in the second period, partially because of the smaller time interval.

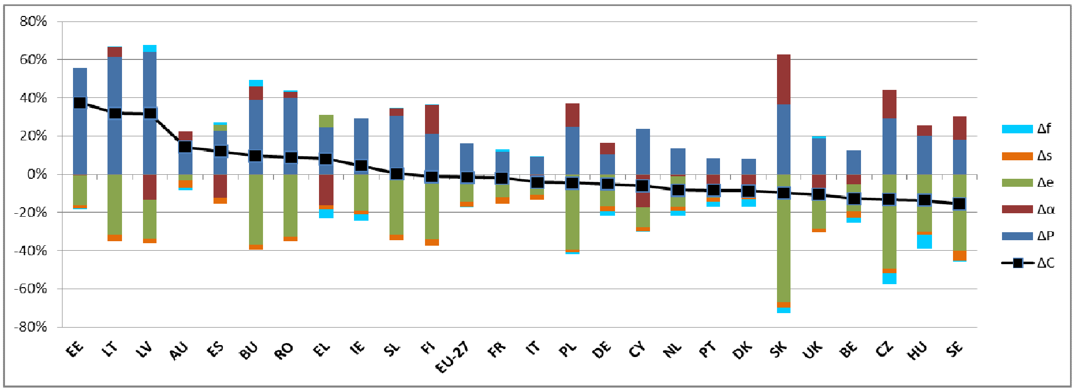

Figure 5: Decomposition of changes in CO_2 emissions in EU countries, 2000-2007.

Comparing the decomposition results across the 25 EU countries, we observe that most of them display similar patterns. They increased their GDP, a development which, if not accompanied by other technological and/or structural changes would have led to a corresponding increase in emissions. At the same time, the energy intensity effect is strongly negative in all countries - except for Greece and Spain – driving down emissions. The energy intensity improvement is stronger in eastern European countries (RO, CZ, SL, HU, PL, SK) than in the western ones, which is expectable given the high energy intensity of these countries, and is largely due to the efforts undertaken by these countries for the modernisation of their production systems and the promotion of energy saving measures. The other three factors play a rather minor role, with changes in the energy and electricity mix mostly reducing emissions and structural effects presenting both types of effects: in some countries, especially in eastern Europe they contribute to rising emissions as a result of shifts from the primary sector to the more energy intensive manufacturing sector. In other countries, their contribution is negative reflecting shifts towards services, but also an increasing share of the construction sector, especially in Greece.

The situation changes considerably after the economic crisis. The results of the decomposition analysis shown in Fig. 6, indicate that in the new conditions, EU countries have followed different patterns to comply with the climate targets.

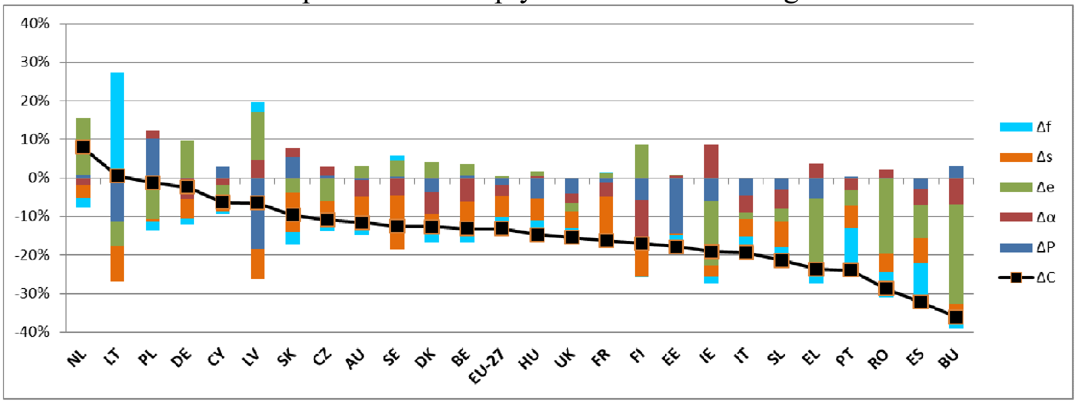

Figure 6: Decomposition of changes in CO_2 emissions in EU countries, 2007-2010.

First of all, in most countries, the drop of GDP pushed down emissions. Energy intensity shows also a double effect: in some countries, it seems to worsen, indicating a less efficient use of energy resources, whereas in other countries with either increasing or decreasing GDP, it continues improving. The effect of structural shifts becomes more apparent and pushes in most countries toward emission reduction, while changes in the energy mix and utility effects appear to have now a more evident contribution to emission reduction. The few exceptions shown in Fig. 6 (LT, LV, SE) are due to a relative decrease of nuclear energy in electricity generation and/or an increase of solid fuels).

By separately investigating the calculated driving factors we obtain a better view on the reasons behind the evolution of CO_2 emissions. Figure 7 shows the effect of economic growth on the percentage change of emissions in the two periods, in parallel with the economic level of each country. It is clearly discernible that the impact of the growth factor is very important during the first period, whereas in the second period it is rather negligible and in most countries negative. Furthermore, it can be seen that the positive impact is higher in countries with lower GDP, indicating the urgent need to combine the right to development with effective measures for sustainability.

Similar results can be drawn by examining the energy intensity effect, shown in Fig. 8. The impact is bigger in less developed eastern countries characterized by high energy intensities, thus by inefficient use of energy. During the second period, the intensity effect becomes less important in all countries, while it is worth noticing that in some highly industrialized countries (NL, DE, FI, DK) there is even a positive effect denoting that in times of economic recession, the productivity of resource use is deteriorating.

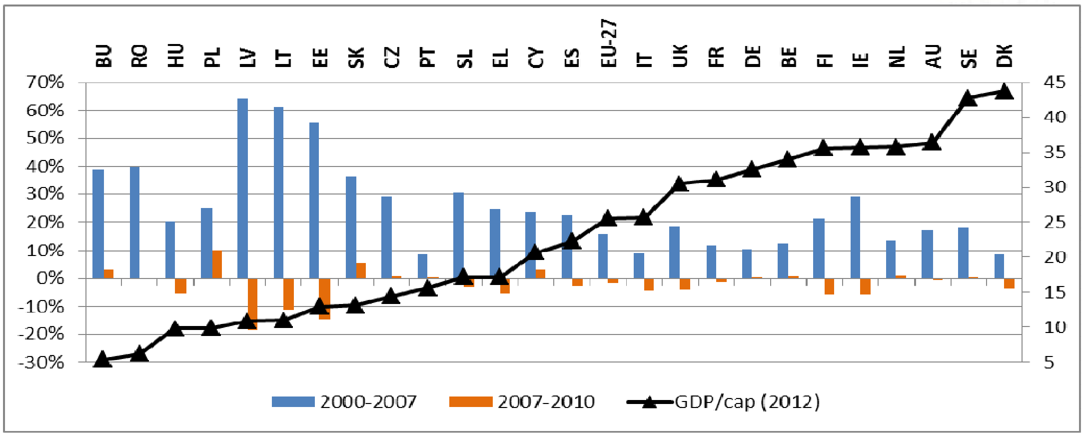

Figure 7: The effect of economic growth on the changes of CO_2 emissions in EU countries

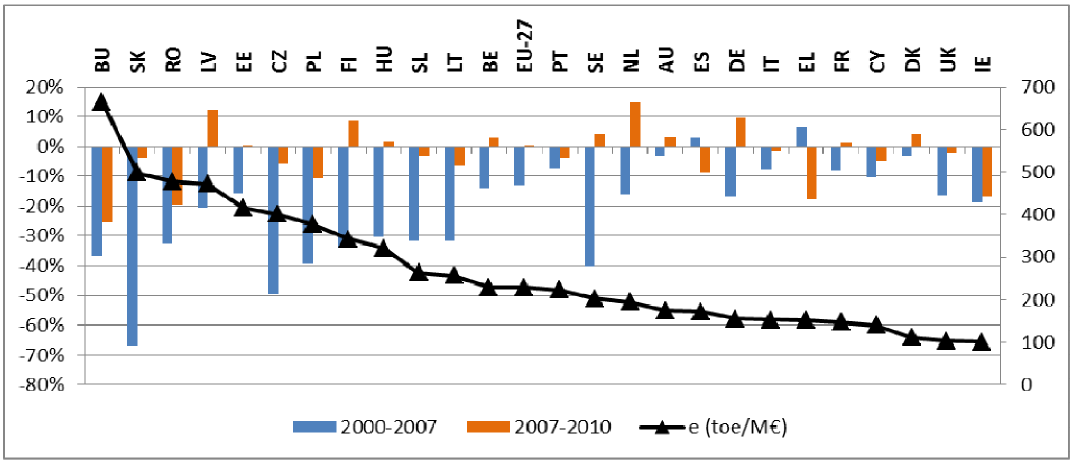

Figure 8: The effect of energy intensity on the changes of CO_2 emissions in EU countries

The effect of structural changes are shown in Fig. 9. During the first period, EU countries are clearly divided in two groups, the one comprising mostly the less developed eastern countries, where shifts to industrial activities result in emission increases. The second group is characterized by shifts towards less energy intensive sectors, mostly services and construction. In the second period structural effects become generally less important and in most cases contribute to emission reduction.

Finally, the effect of energy mix is shown in Fig. 10. It is clear that all EU countries have undertaken significant efforts to promote cleaner fuels and RES in their energy mix, that helped reduce CO_2 emissions, although this effect was smaller compared to other driving factors. It is notable that with a few exceptions, the penetration of clean energy forms was greater after the economic crisis, proving the gradual market maturity and the increasing competitiveness of relevant technologies.

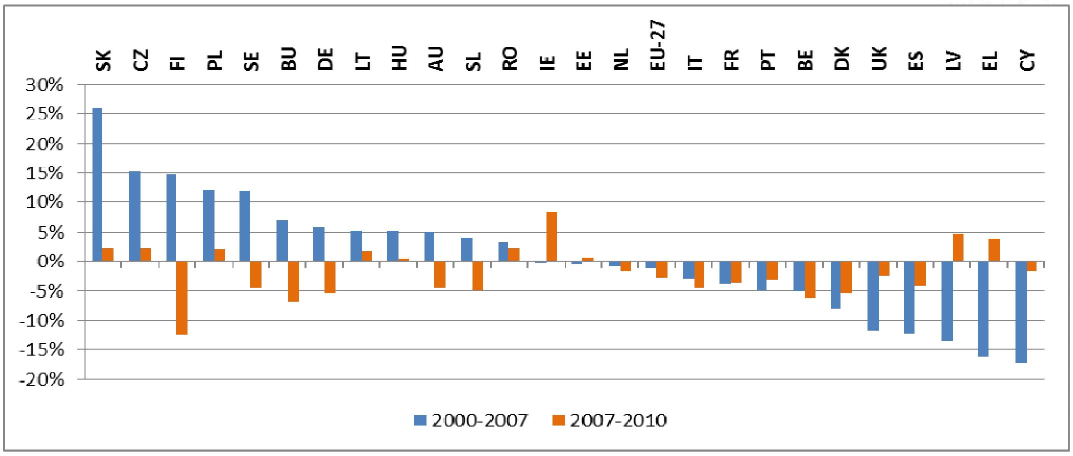

Figure 9: The effect of structural shifts on the changes of CO_2 emissions in EU countries

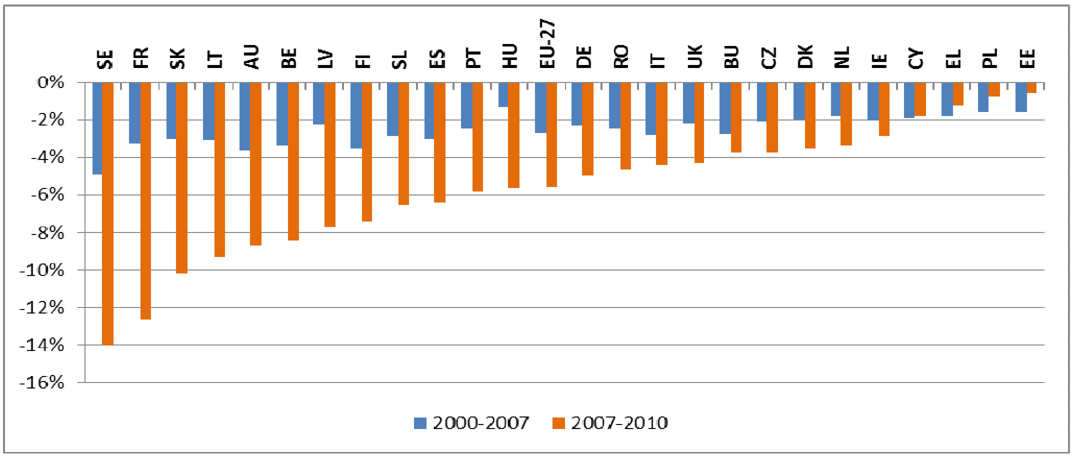

Figure 10: Relative effect of energy mix on the changes of CO_2 emissions in EU countries

5. Concluding remarks

Climate change is a major challenge for the global society. It becomes all the more clear that the process of development of the world economy should follow a sustainable path. The European Union played a leading role in past international agreements and steadily promotes policies and measures aiming at a low carbon sustainable economy. Clean energy technologies, in particular energy saving and exploitation of RES constitute the cornerstone of the European policy to combat climate change.

Based on the idea that understanding the past can be a useful guide for the future, our aim was to uncover the explanatory factors behind the evolution of CO_2 emissions in each EU country during the period 2000-2010. To this purpose, a decomposition analysis approach has been implemented by developing a decomposition model relying on the Log Mean Divisia Index I method.

It was found that in times of prosperity, countries proceed to transformations and technological improvements allowing for a more efficient use of resources. In fact, the improved energy intensity was the main factor that restricted the rise in CO_2 emissions associated with the increased output. Nevertheless, the fuel mix in the economy and in the electricity generation sector seems to play a minor role to emission reduction. The picture is quite different during the economic recession, with energy intensity effect becoming less evident or even contributing to emissions rise, while changes in the fuel mix appear as the major driver to emission reduction. Finally, structural changes had a limited effect in both periods, although the shift toward the service sector appears to contribute to emission reduction, especially in the most developed EU countries.

It can be deduced that for successfully meeting the targets of sustainability for 2020, the recovery of the European economies should be associated with greater efforts to further improve energy productivity, especially in high energy-intensive sectors and in less developed eastern EU countries. Moreover, it seems that there is enough room to carefully design sectoral shifts towards a knowledge driven economy based on "smart" innovative concepts and processes that can boost growth without environmental side-effects.

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Environmental Management Systems in SMEs – The Impact of the Economic Crisis

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Abstract
This paper aims to re-evaluate the prior research findings on the literature relating to environmental management systems (EMSs) within the context of the financial crisis. The research focuses on five core interrelated categories of EMS literature: driving forces, environmental aspects, environmental performance, challenges and barriers and institutional assistance. The findings indicate that even though the majority of the respondents agree that the economic crisis may lead firms to be more reluctant to adopt EMS, nevertheless current environmental legislation could counterbalance this trend and still promote EMS implementation. Some of the respondents declared that the EMSs will help achieve financial savings as well as additional benefits from an increase in the share market due to newly-developing and promising international green markets. However, some of the respondents view EMS adoption in the current economic crisis as additional costs which could be minimized with the help of government.

Keywords: ISO 14001, SMEs, environmental regulations, sustainable development.

1. Introduction
Small and medium-sized enterprises (SMEs) comprise the majority of businesses worldwide. Hillary (2004) observed that over 90% of the global business community consists of SMEs and are responsible for over 70% of total environmental pollution. Gadenne *et al.* (2009) explained that even though each SME, by size, are considered as having low impacts on the natural environment, their total aggregate amount of pollution impacts can be higher than the impacts of large firms. Specifically, the impacts of SMEs on the natural environment relate to natural resources' consumption (e.g. raw materials, water use, and energy use) and damage to environmental quality (e.g. air pollution, wastewater, solid waste).

To this end, various stakeholders recognise the potential contribution of SMEs to economic development but also to environmental degradation. A representative example can be taken from the financial world (e.g. the banking and insurance sectors) that has recently introduced a range of environmental criteria into lending processes and insurance contracts to minimise potential financial risks that could emerge from possible environmental accidents or penalties from the non-compliance of SMEs with environmental regulations (Weber *et al.*, 2010). Further evidence is provided by the recent and promising environmental consciousness of consumers that can be translated into purchasing choices in favour of environmentally friendly products and services (Perez-Sanchez *et al.*, 2003).

In line with such requests, governments have instituted explicit environmental policies to establish a consistent system of rights and obligations of the business community to a high-quality natural environment. Literature classifies environmental policy into three categories: command and control policies (e.g. air pollution legislation), market-based policies (e.g. environmental taxes) and government assistance policies (e.g. technical and educational assistance) (Tsireme *et al.*, 2012). Such policies aim to modify the behavior of firms from a conventional to a more environmentally friendly position while still considering financial concerns (costs and benefits). Under these circumstances, some SMEs adopt EMSs, reactively or proactively, to control their pollution. The literature on SMEs and EMSs has recently emphasized some common research facets such as the driving forces that play a crucial role in the decision of firms to adopt EMSs, the types of environmental aspects addressed within EMSs, the level of environmental performance, the challenges and barriers to adopting EMSs and, finally, the suitable institutional framework for encouraging SMEs to adopt EMSs (Peters and Turner, 2004; Caska *et al.*, 2004).

This paper aims to re-examine some of these research areas and the findings of previous EMSs studies in the light of the harsh financial challenges of the contemporary crisis. The critical point of this paper is the analysis of management attitudes in SMEs to a variety of research topics such as the drivers of EMSs, the environmental aspects covered by EMSs, the environmental performance of SMEs, the challenges and barriers to implementing EMSs and the necessity of additional assistance for SMEs in adopting EMSs under the conditions of economic crisis. Through a case study research methodology, an analysis of current topics is conducted in a sample of EMS certified Greek SMEs.

The rest of the paper is classified into four sections. The second section includes the literature review of EMS literature within the context of driving forces (why), EMSs practices and aspects (how), performance (outcomes), challenges and barriers (costs and benefits) and stakeholders' involvement (institutional framework). The third section analyzes the case study methodology that includes research structure, coding system, sample selection and protocol development. The fourth section includes the results, while the final section includes the conclusions and discussion (Studer *et al.*, 2006).

2. Background

Much of the literature of corporate environmental management has recently focused on SMEs and EMSs (Biondi*et al.*, 2000; Zobel, 2007). EMS is a management tool that is voluntarily adopted by firms in their effort to respond to economic and environmental challenges (win-win situation). The most well-known EMSs are ISO 14001 (under the auspices of the United Nations) and EMAS (supported by the European Union). EMS implementation also requires some standard and sequential steps such as the preparation of an environmental policy, the implementation of environmental programmes, the auditing , and the management review (Zutshi and Sohal, 2004).

Some fundamental research topics on SMEs and EMSs have recently been published in the current literature. The analysis of the literature highlights some fundamental and interrelated research questions as follows: (a) Why do SMEs adopt EMSs? (b) How do SMEs implement EMSs? (c) What are the environmental outcomes of SMEs? (d) What are the challenges of and barriers to adopting EMSs for SMEs ? And (e) What institutional incentives are needed to encourage SMEs to adopt EMSs?

Current studies explore the key driving forces behind SMEs voluntarily adoption of EMSs. Various factors affect the decisions of SMEs to adopt EMSs. Some important drivers fall into two groups, state-regulated and self-regulated incentives. The former category consists of *"command and control" (CAC)* and *"market-based" (MB)* instruments that are instituted by governments either to encourage or indirectly pressure SMEs to participate in formal EMS certification programs (Bianchi and Noci, 1998; Wlliamson *et al.*, 2006). The latter category considers the voluntary adoption of EMSs by SMEs either as result of potential financial earnings or the ethical priorities of managers to protect natural resources (McKeiver and Gadenne, 2005; Studer *et al.*, 2006). Others explained such voluntary environmental strategies of SMEs as an effect of stakeholder pressure (Gadenne *et al.*, 2009). Miles *et al.* (1999) stated that formal EMSs (e.g. ISO 14001) improve corporate profile and facilitate cooperation with regulators, green consumers, employees and Non-Governmental Organizations (NGOs).

Regardless of the state– or self–regulated origin of drivers, they primarily affect the decision of SMEs to adopt a range of alternative environmental management practices. The important question here is how SMEs respond to the targets within an EMS context? The response to such question requires a clear definition of environmental management practices. Montabon *et al.* (2007) defined environmental management practices as *"the techniques, policies and procedures a firm uses that are specifically aimed at monitoring and controlling the impact of its operations on the natural environment"* (p. 998). Some further environmental management practices could make the concept clearer such as (a) the multiple– or single–based emphasis (*e.g.* only water management or multiple environmental facets), and (b) the formal or informal character. Formal environmental management practices are those certified by national and international organizations (e.g. ISO 14001 and EMAS), while informal environmental management practices are voluntarily adopted (e.g. green purchasing and cleaner technologies) in the absence of a formal third party certification body (Shaper, 2002; S-Yol Lee, 2008).

The successful implementation of environmental management practices is mainly tested through performance measurements for a range of environmental targets (Kerr, 2006). Montabon *et al.* (2007) analyzed such targets in energy, solid waste management, wastewater and air pollution. According to Rondinelli and Vastag (2000), wastewater treatment, water conservations, solid waste management, chemical auditing, air emissions control, storm water pollution prevention, spill prevention, and countermeasure plans are successfully addressed with the implementation of formal EMSs. However, Lefebvre *et al.* (2003) considered that environmental performance should be measured in different levels hence they proposed three types of indicators for measuring the environmental concerns of SMEs: product life cycle, operation level, and R&D.

However, in their effort to voluntarily adopt EMSs, SMEs have faced either barriers or challenges. Hodgson (1995) showed that some crucial barriers are limited financial resources and the lack of sufficient environmentally trained staff. Hillary (1995) supported that the perception of managers for minimal impacts of SMEs on the natural environment have deterred SMEs from adopting integrated environmental management programs. Some other barriers are a lack of time and technical knowledge and bureaucracy related to environmental issues (Revell and Rutherfoord, 2003). On the other side, Miles *et al.* (1999) supported that the implementation of ISO 14001 environmental standards is expected to offer various benefits to SMEs such as a better profile, insurance contracts cost cutting and acceptance within the market.

Finally, an important part of literature examined the role of local authorities in supporting the efforts of SMEs to protect the natural environment. Combault and Versteege (1999) focused on how local authorities can assist SMEs in eliminating their environmental impacts. Similarly, Clement and Hansen (2003) identified that various types of financial assistance are offered by European governments to facilitate SMEs in adopting environmental management practices. According to Bradford and Fraser (2008), local authorities could support energy strategies through a range of measures such as energy price increasing, suitable information programs for energy savings, financial incentives and essential energy standards. Peters and Turner (2004) also presented the significant role of local authorities in assisting SMEs in improving their environmental performance. Similarly, von Malborg (2007) explored the role of local authorities in promoting learning and innovation in issues related to environmental management.

3. Method

3.1 Research questions

This research aims to re-examine some key research topics and findings arising from previous studies of environmental management systems (EMSs) and SMEs through the view of the current economic crisis. The research structure is illustrated in Figure 1. The main research components of the research are: a) the driving forces (financial benefits and moral commitments) that affect the decision of SMEs to adopt ISO 14001, b) the barriers and challenges for SMEs in adopting formal EMSs, c) the types of management practices which SMEs implement in the context of EMSs, d) the level of the performance for each environmental aspect (e.g. energy and water use), e) the potential assistance for SMEs in maintaining EMSs under the context of the economic crisis.

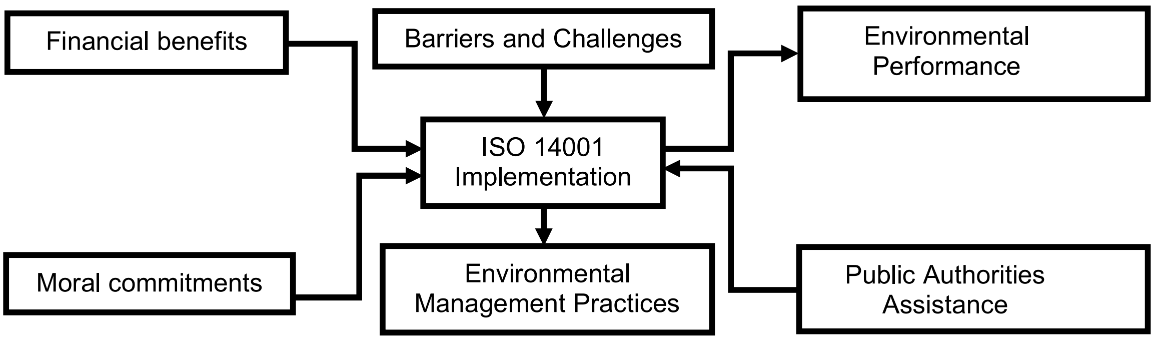

Figure 1: Research structure

Some important and interrelated questions to be addressed in this paper are as follows:

What are the drivers that play a critical role in the decision of SMEs in maintaining EMSs in the event of a financial crisis?
What are the practices and environmental aspects that are covered by EMSs in a financial crisis?
What is the level of environmental performance of SMEs in a financial crisis?
What are the barriers and challenges for SMEs in maintaining EMSs in the financial crisis?
Are public authority tools essential to encourage SMEs to maintain EMSs?

3.2 Methodology

This research is based on the case study research methodology. It is considered an appropriate methodology for testing research questions and examining scientific fields where current knowledge is very limited. Case study research assists in developing *"empirical enquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident"* (Yin, 1994: 13). Eisenhardt and Graebner (2007) supported that case study research methods utilize qualitative information in order to build a more comprehensive research.

3.3 Protocol development

The protocol includes 36 questions classified into five sections. The first section explores a range of key drivers that could play a crucial role in the decision of SMEs in maintaining ISO 14001. For example, some interesting questions of this section are the request of financial stakeholders with regards to corporate environmental protection, the requirements of environmental legislation for SMEs regarding pollution prevention and the increasing requirement of suppliers for environmental management practices. Such questions stem from recent well-known pressure from the banking and insurance sectors that require information about corporate environmental performance in order to moderate potential financial failures associated with possible environmental accidents as well as relevant requirements of green procurement and purchasing.

The second section addresses questions on environmental management practices in the context of ISO 14001. Six questions seek to identify the intentions of firms about the types of environmental management practices maintained within the context of the current financial crisis. To this end, energy, solid waste management, reuse and recycling, and water consumption are examined. In the third section, various questions on SMEs' environmental performance are examined such as the level of energy savings, the level of recycling, the amount of wastewater treated, and the number of accidents which have taken place in the past.

The fourth section examines the potential barriers and challenges to SMEs of maintaining ISO 14001 under the current economic crisis. Some indicative questions are whether the improvement of staff skills and working conditions through ISO 14001 are good reasons for maintaining it. Cost savings and customer satisfaction could be crucial motivations for maintaining ISO 14001. Also, whether operational costs of ISO 14001 and bureaucracy are significant barriers for maintaining ISO 14001 will be addressed The final section examines the additional assistance that is necessary for SMEs to maintain ISO 14001.

3.4 Coding System

Data analysis was based on the coding system stemming from the work of Pagell and Wu (2009). This system is a rigorous way to assess data and an important technique to reduce the high amount of data that usually arises from case study research. Here, this system assists in identifying the extent to which various factors might affect the decisions of SMEs to maintain ISO 14001 under the current economic crisis. Table I describes the meaning of the basic symbols of the coding system.

Table 1: Description of Symbols

Symbol	Description
Y	Yes, this factor is important
N	No, this factor is unimportant
L	Limited importantance of this factor

3.5 Data collection

The questionnaire was distributed to the senior management and the member of staff responsible for environmental issues. The sample contains eight SMEs certified by ISO 14001 located in Northern Greece and operating in various industrial sectors such as ***mattresses and furniture****, metal* ***construction, aluminum****,* ***abrasive products****,* ***flexible packaging****,* ***environmental systems,*** *pulp and paper, and plastic.*

Table 2 also shows the characteristics of respondents. 80% of the sample was men and 20% women. The age of respondents ranges from 30 to 55 years old.

Table 2: Age of respondents

Age	Respondents	%
27-30	3	37.5
31-40	2	25
41-50	2	25
51-55	1	12.5
Total	**8**	**100**

4. Analysis of results

4.1 The drivers that play a critical role in the decision of SMEs to maintain EMSs

Table 3 illustrates the significance of various driving forces for the firm sampled. Findings show that the majority of sampled firms considered pressure from stakeholders (e.g. consumers and government) less important for maintaining EMSs in the future. The respondents supported that environmental regulation remains a significant driving force for maintaining EMSs. Suppliers' pressure, corporate profile and local license to operate could also be good incentives for some firms sampled. All the firms considered attracting employees as a less important incentive.

Table 3: Driving forces for maintaining EMSs

Questions*	The answers of respondents**							
	F_1	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**	**F_7**	**F_8**
1	N	N	N	N	N	N	N	Y
2	N	Y	N	N	Y	Y	Y	Y
3	N	Y	N	Y	Y	Y	N	Y
4	N	Y	N	N	Y	Y	N	Y
5	N	L	L	L	L	L	N	N
6	N	N	N	N	N	N	N	N
7	N	N	L	L	L	N	Y	L

*Appendix A, **Appendix B

4.2 The practices and environmental aspects covered by EMSs

Table 4 indicates environmental management practices which managers are willing to maintain in the economic crisis such as energy savings, solid waste reduction, reuse of materials, water use savings, air pollution control, and environmental education of employees.

Many of the respondents intend to maintain energy strategies. The majority declared that low energy light labs could be a good strategy. Only two respondents considered future energy conservation very important while three respondents aimed to install metal frames for insulation. Others aim to change older air-conditions with new inverter technology. Metallic construction firms plan to meet over of 30% of energy needs from renewable energy sources.

Table 4: Environmental management practices implementation through EMSs

Questions*	The answers of respondents**							
	F_1	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**	**F_7**	**F_8**
8	L	Y	Y	L	L	N	L	L
9	Y	Y	Y	L	L	N	Y	L
10	Y	Y	Y	L	Y	L	Y	Y
11	N	Y	Y	L	N	Y	N	L
12	L	L	Y	L	N	N	Y	N
13	Y	Y	Y	Y	Y	Y	Y	Y

*Appendix A, **Appendix B

Some respondents aim to maintain techniques for water savings, while others are reluctant to implement any technique for water conservation due to limited impacts on water resources. A limited number of respondents intend to adopt sprinkler timers for watering green spaces. In particular, a firm in the 'environmental services' sector aims to maintain present innovative water conservation technique which assists in reusing water from production procedures. The firm in 'metallic sector' plans to complete investment in a waste water utility treatment with capacity to process over 80% of polluting water resources.

The majority of respondents intend to maintain some of the current air emission control practices, while others explained their reluctance to maintain as a result of the low air pollution impacts of their operations. Firms in the ‘metallic and abrasive sector’ plan to carry out regular maintenance on their boilers. Firms in the packaging sector intend to maintain the current system for recovering solvent vapors which result in 90% reuse. A firm in the aluminum sector aims to organize production process so that raw materials will not include CFCs and HCFCs. Finally, all respondents will continue with financial training programs for the environmental education of their employees.

4.3 The level of environmental performance of SMEs

Table 5 illustrates a range of environmental performance issues.

Table 5: Environmental performance issues

Questions*	**The answers of respondents****							
	F_1	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**	**F_7**	**F_8**
14	N	Y	Y	L	N	N	Λ	O
15	L	L	N	L	Y	L	L	Y
16	N	N	N	N	N	Y	N	N
17	N	N	N	N	N	N	N	N

*Appendix A, **Appendix B

Only two respondents have provided specific information about energy performance. A firm metallic and one in window frame sector achieved 25% and 30% energy savings respectively on an annual basis, and they plan to improve these targets in the future. Despite the fact that firms in the ‘furniture and abrasive sectors’ stated that energy conservation figures reached 15% and 6% respectively, the consequences of the economic crisis will play a critical role in maintaining current energy conservation efforts.

Regarding recycling practices, a firm in the ‘window frame sector’ has achieved a rate of 20% in paper recycling and 90% for raw materials recycling. However, the majority of respondents intend to implement recycling practices mainly for paper. For wastewater recycling, some respondents declared low impacts and thus are not intending to invest in specific treatment practices. A firm in ‘metallic sector’ aims to maintain the current practice of treating 90% of wastewater, while a firm in the furniture sector has set a target of 100% of wastewater treatment in the near future. Finally, it is worth noting that all firms have had no environmental accidents.

4.4 The barriers and challenges for SMEs in maintaining EMSs

Table 6 shows the barriers and challenges for EMS adoption in the economic crisis.

Respondents declared improvements in the health and safety of working conditions. Three respondents have achieved cost savings from energy and waste production strategies, while the others stated that the relationship between environmental management practices and financial performance is unclear. Some of the respondents intend to interrupt some of their recent environmental management programs practices as a result of indistinct benefits and the effects of the economic crisis. Many of respondents observed a progress in the dialogue with their employees, while two did not identify any such improvement.

Despite the majority of respondents not identifying an increase in their market share, they recognized a degree of satisfaction from existing customers. Two respondents noticed a slight increase in their exports. It should be highlighted that all respondents noted the improvement in employee performance after the implementing of environmental management practices.

Finally, respondents considered the cost of the implementation and maintenance of ISO 14001 in the midst of an economic crisis to be an important barrier. The majority of respondents considered that bureaucracy would also hinder maintaining ISO 14001 in the future. Conversely, two firms – one in the furniture and one in the environmental services sectors - considered that bureaucracy is not a barrier for maintaining ISO 14001.

Table 6: Challenges and barriers from EMSs adoption

Questions*	**The answers of respondents****							
	F_1	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**	**F_7**	**F_8**
Challenges								
18	Y	Y	Y	Y	Y	Y	Y	Y
19	L	Y	Y	Λ	Y	L	L	L
20	Y	Y	Y	Y	Y	Y	N	N
21	L	Y	L	L	L	Y	N	N
22	Y	Y	Y	Y	Y	Y	Y	Y
23	Y	Y	Y	Y	Y	Y	Y	Y
24	Y	Y	Y	Y	Y	Y	Y	Y
25	N	L	Y	L	Y	Y	Y	L
26	N	N	N	N	N	L	N	N
Barriers								
27	Y	Y	Y	Y	L	L	Y	Y
28	N	N	N	N	L	N	N	N
29	Y	Y	Y	Y	Y	N	N	Y
30	N	L	N	N	N	N	N	N
31	N	N	L	L	L	N	N	N
32	N	N	N	N	Λ	N	N	N

*Appendix A, **Appendix B

Public authorities tools essential for encouraging SMEs to maintain EMSs

Table 7 shows types of external assistance suitable for encouraging firms to maintain existing environmental practices.

Table 7: Public assistance

Questions*	**The answers of respondents****							
	F_1	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**	**F_7**	**F_8**
33	N	Y	Y	Y	Y	Y	Y	Y
34	Y	Y	Y	Y	Y	N	Y	Y
35	Y	Y	L	L	L	Y	Y	Y
36	Y	Y	Y	Y	Y	Y	L	Y

*Appendix A, **Appendix B

The vast majority of respondents considered that subsidies are good incentives for supporting present environmental practices in the future. Conversely, a firm in the window frames sector stated that subsidies do not play a critical role in continuing its environmental programs. Some respondents judged that technical assistance from public authorities could be necessary in the future.

5. Conclusions

This paper aims to contribute to current literature by re-examining some common research questions of corporate environmental management literature under the current economic crisis. For the first research question, findings show that the most important driving force is environmental legislation, critical for respondents in order to maintain EMSs. This is in line with the findings of many of the present studies that indicate a positive relationship between environmental legislation and managers' decisions to implement environmental management practices (Zorpas, 2009). Another critical factor that influences SMEs to maintain environmental management practices is the improvement in their image and their relations with local communities. Corresponding findings emerge from Zutshi and Sohal's (2002) work that indicate improved relations of firms with local communities could represent a good stimulus for SMEs to adopt environmental management practices.

Even though there is no clear answer from respondents for the second research question, there are nevertheless some shared insights. The majority of respondents intend to adopt energy management practices, a fact that is confirmed by the work of Chan and Li (2001), who claimed that SMEs considered EMS adoption *"as a promotional tool and as an energy– and resource–saving measure"* (p. 593). Additionally, many respondents considered the increase in their market share and the identification of new niche markets as a very important stimulus for maintaining EMSs. However, the majority of respondents raised significant doubts about having the financial means to support EMS processes due to the impact of the financial crisis.

For the fourth research question regarding environmental performance, the majority of respondents were willing to continue with current levels of recycling and wastewater treatment targets. Lee (2009) identified relevant findings in his investigation in South Korea where a range of wastewater management practices were adopted to reduce wastewater production and remove the glue components from their products of firms examined. Finally, the majority of respondents considered government subsidies very promising tools for maintaining EMSs, a fact confirmed by Chen *et al.* (2003) who identified that the lack of governmental financial support could play a critical role in maintaining EMSs.

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Appendix A

First Section: Driving forces	
1	Stakeholders' pressures
2	Environmental legislation
3	Competitive advantage
4	Local community acceptance
5	Greening supply chain
6	Attracting employees
7	Environmental management commitments
Second section: Environmental Aspects	
8	Do you implement energy strategies?
9	Do you implement solid waste management?
10	Do you implement strategies for reuse of materials?

11	Do you implement water saving strategies?
12	Do you implement air pollution control strategies?
13	Do you implement environmental training programs?
Third section: environmental performance (%)	
14	Energy savings
15	Recycle materials
16	Wastewater treatment (in tonnes)
17	Environmental accidents
Four Section: challenges and barriers	
A. Challenges	
18	Improved working conditions
19	Cost savings
20	Better dialogue with employees
21	Increase share market
22	Improved educational quality
23	New environmentally friendly products
24	Better environmental awareness of employees
25	Competitive advantage
26	Improved image
B. Barriers	
27	High cost of what?
28	Lack of expertise
29	High levels of bureaucracy
30	Additional administration responsibilities
31	Lack of motivation amongst employees
32	Resistance of employees to new innovations
Fifth Section: Public assistance	
33	Subsidies
34	Less bureaucracy
35	Technical assistance
36	Information assistance

Appendix B

Symbols	Description
F_1	Furniture company
F_2	Metallic construction company
F_3	Aluminum windows frames company
F_4	Abrasive company
F_5	Packaging company
F_6	Environmental services company
F_7	Wood company
F_8	Plastic company

Learning the dynamics of climate change: An experimental analysis

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ABSTRACT
This paper analyzes the role of experiments in learning the dynamics of greenhouse gases (GHGs) and climate change. In a framework of repeated feedback, the effect of the rate of CO2 absorption by the atmosphere and the stochastic nature of climate change and economic systems is analyzed, using a Dynamic Climate Change Simulator with Stochastic and Irreversible Climate Change (DCCS-SICC). DCCS-SICC is a simplification of the complex climate system into its essential elements of man-made CO2 emissions, CO2 concentration, and natural CO2 absorption in the atmosphere, with business cycle shocks and climate change tipping points. Participants' ability to control CO2 concentration to a goal level is analyzed and insights are provided about how learning about the dynamics of the Earth's climate can be assisted.

Keywords: Complex adaptive systems; repeated feedback; climate change; dynamic Learning.

JEL Classification: Q54; C91; D83.

1. Introduction

The global climate system is complex and its response to future anthropogenic GHGs, climate change adaptation, is often poorly understood. Climate change adaptation is an area where modeling in the framework of complex adaptive systems could improve our knowledge both with respect to the internal structure and adaptive mechanisms of climate and our capacity for designing efficient climate adaptation policies. Modeling of these systems includes a dynamic system consisting of transition equations describing the evolution of state variables characterizing the natural system, such as CO2 concentrations in the upper and lower atmosphere and in the oceans, and state variables characterizing the economic systems, such as physical capital and knowledge. The complex adaptive character of the system implies that the dynamical system will be nonlinear and nonconvex to allow for nonlinear feedbacks and multiple basins of attraction, will evolve both in the temporal and spatial dimension, and will be influenced by forward looking optimizing economic agents (Xepapadeas, 2010).

Moreover, any rational policy choice must consider the great uncertainty about the magnitude and timing of climate change's impact on economic productivity. (Cai *et al.,* 2013). The majority of the literature, including the recent U.S. Government Interagency Working Group on the Social Cost of Carbon (IWG, 2013) does not model the stochastic nature of the climate and economic systems. Recent work, such as that of Cai *et al.* (2013) has developed a dynamic stochastic model that incorporates the mutual interplay between climate and economics, employing a stochastic business cycle at the annual time scale and a stochastic climate tipping point system. Lenton and Ciscar (2013) describe examples of tipping points for some major elements of the climate system: abrupt loss of Arctic summer sea-ice, irreversible meltdown of the Greenland ice sheet (GIS), disintegration of the West Antarctic ice sheet (WAIS), reorganization of the Atlantic thermohaline circulation (THC), increased amplitude of the El Niño Southern Oscillation (ENSO), disruption of the Indian summer monsoon (ISM), collapse of the West African monsoon (WAM), dieback of the Amazon rainforest, and dieback of boreal forests.

However, the realistic representation of climate change and economic dynamics using complex adaptive systems comes at a cost. Climate change is a complex dynamic system with important challenges for its perception and understanding from policymakers and the general public (Bostrom *et al.,* 1994; Moxnes and Saysel, 2009; Reynolds *et al.* 2010). Empirical observations suggest that individual agents do not understand accumulation processes (the transition equations describing the evolution of state variables) even in simple dynamic systems that include a single state and a single control variable (Cronin and Gonzalez, 2007; Cronin *et al.,* 2009; Dutt and Gonzalez, 2012; Sterman and Sweeney 2002; Sterman and Sweeney 2007). Moreover, Cronin *et al.* (2009) have shown that even individuals with a strong background in mathematics and sciences fail to interpret the basic principle of dynamic systems, that a stock (state variable) rises when the inflow rate exceeds the outflow rate.

In the present paper, first a simplified dynamic programming model is developed built upon prior studies (Cai *et al*., 2013; Cai *et al*., 2012; Nordhaus, 2008) that models a stochastic business cycle at annual time scale and a stochastic and irreversible climate change tipping point. The dynamic programming model is then utilized to build an interactive and dynamic stock-management simulation, based on the DCCS model (Dutt and Gonzalez, 2012) that incorporates both a business cycle shock and a stochastic and irreversible climate change tipping point, the Dynamic Climate Change Simulator with Stochastic and Irreversible Climate Change (DCCS-SICC). DCCS-SICC is employed to investigate individual agent's ability to control CO2 concentration in the atmosphere to a goal level under different scenarios. The main objective of the paper is to investigate why individuals exhibit poor control over the dynamic systems in the context of climate change, and to provide suggestions about how these problems can be resolved.

The rest of the paper is organized as follows: Section 2 presents a simplified dynamic model of the earth's climate, Section 3 presents the Dynamic climate change simulator with stochastic and irreversible climate change (DCCS-SICC), Section 4 presents the experimental design, Section 5 presents the results of the experiment and the final section concludes.

2. Model specification

For the purpose of the present study, we employ a simplified version of DSICE (Cai *et al*., 2012), a dynamic stochastic general equilibrium model integrating climate and the economy. DSICE is a version of DICE 2007 (Nordhaus 2010) with a flexible time-period length. DSICE incorporates both uncertainty about the future state of climate and the economy.

Let M_t describe carbon concentrations in the atmosphere. These concentrations evolve over time according to

$$M_{t+1} = \sqrt{}^{M} M_t + (\Sigma_t)^T \tag{1}$$

where, $\sqrt{}^{M}$ is the pre-industrial equilibrium state of the carbon cycle system. The anthropogenic sources of carbon are represented by ε_t. Temperature in the atmosphere, T_t^{AT}, evolves dynamically according to

$$T_{t+1}^{AT} = \sqrt{}^{T} T_t^{AT} + (\xi_1 F_t(M_t^{AT}))^T \tag{2}$$

where $\sqrt{}^{T}$ is the heat diffusion process and ξ_1 is a climate sensitivity parameter. Atmospheric temperature is affected by external forcing F_t^{EX} and by the interaction between radiation and atmospheric CO2, implying the total radiative forcing is

$$F_t(M^{AT}) = / \log_2(M^{AT}(M_0^{AT}) + F_t^{EX} \tag{3}$$

The impact of global warning on the economy is reflected by a convex damage function of temperature in the atmosphere, as in DICE 2007, that includes the possibility of a climate shock (tipping point) to account for the threat of abrupt and irreversible climate change. Each climate shock occurs at a random time. The stochastic damage factor is given by

$$\Omega(T^{AT}, J_t) = \frac{1 - J_t}{1 + \pi T_t^{AT} + \pi_2 (T_t^{AT})^2} \tag{4}$$

where the denominator represents the standard damage function from DICE 2007 and J_t is a discrete Markov chain with nondecreasing values over time, with J_t=0 in the pre-tipping regime (stage 1) and 0<J_t<1 in all subsequent stages of the post-tipping regime. J_t is the persistent climate damage state representing the irreversible nature of the tipping point (see Cai et al. 2013 for more).

The capital stock k_t transits to the next period according to

$$k_{t+1} = (1 \square \delta) k_t + y_t(k_t, T_t^{AT}, \alpha_t, /_t, J_t) \square c_t \tag{5}$$

where y_t denotes the stochastic production function and includes the damage resulting from global warming as well as both an economic shock and a climate shock:

$$y_t(k_t, T_t^{AT}, \mu_t, \zeta_t, J_t) = (1 - \theta_{1,t} \mu_t^{\theta_2}) \zeta_t A_t k_t^{\alpha} l_t^{1-\alpha} \Omega(T_t^{AT}, J_t) \tag{6}$$

where ζ_t is a discrete-time bounded mean-reverting continuous productivity shock representing economic fluctuations and its transition function is $\zeta_{t+1} = g^{\zeta}(\zeta_t, \omega_t^{\zeta})$ where ω_t^{ζ} is an i.i.d. random process. The economic shock and the climate shock are independent.

Stochastic and irreversible climate change is modeled as a low-probability and low-impact event and business cycle shocks are moderate and bounded.

Given the stochastic production function, annual total carbon emissions are stochastic and given by

$$\varepsilon_t(k_t, \mu_t, \zeta_t) = \sigma_t(1-\mu_t)\zeta_t A_t k_t^{\alpha} l_t^{1-\alpha} + \mathrm{E}_t^{Land} \tag{7}$$

where σ_t is the carbon intensity of output, μ_t is the fraction of mitigated emission and E_t^{Land} is an exogenous rate of emissions from biological processes.

The standard separable utility function in the finite-horizon DICE2007 is

$$u(c_t, l_t) = \frac{(c_t / l_t)^{1-\psi}}{1-\psi} l_t \tag{8}$$

where c_t is consumption and l_t is total labor supply. It is assumed that a social planner maximizes the present-discounted utility stream up to a terminal time T.
The dynamic programming formulation of the model is:

$$V_t(k, \mu, T, \zeta, J) = \max_{c,\mu} \tag{9}$$

$$u(c_t, l_t) + \frac{\beta}{1-\gamma} x \left[E \left[(1-\gamma) V_{t+1}(k^+, M^+, T^+, \zeta^+, J^+) \right]^{\frac{1-\theta}{1-\gamma}} \right]^{\frac{1-\gamma}{1-\theta}}$$

s.t.

$$k^+ = (1-\delta)k_t + y_t(k_t, T^{AT}, \omega_t, \zeta_t, J_t) - c_t$$

$$M^+ = \Phi^M M_t + \Sigma_t^T$$

$$T^+ = \Phi^T T_t^{AT} + (\xi_1 F_t(M^{AT}))^T$$

$$\zeta^+ = g^{\zeta}(\zeta, \omega^{\zeta})$$

$$J^+ = g^J(J, T^{AT}, \omega^J)$$

for t=0,1,...,100. In the model, consumption c and emission control μ are the two control variables, (k, M, T, ζ, J) is an 8-dimensional state vector at t and (k^+,M^+,T^+, ζ^+, J^+) is its next-year state vector (Cai et al., 2013). The model is further simplified in the experimental design section (Section 4).

3. Dynamic climate change simulator with stochastic and irreversible climate change (DCCS-SICC)

The dynamic programming model was then translated into a simulation user interface, which can be controlled by individual agents, the dynamic climate change simulator with stochastic and irreversible climate change (DCCS-SICC). The DCCS-SICC was built on the DCCS climate change simulation of Dutt and Gonzalez (2012) and was based on previous work by Gonzalez and Dutt (2011) and Moxnes and Saysel (2009). The user interface presents a single state variable (CO2 concentration in the atmosphere), two sliders for controlling the levels of CO2 emissions from fossil fuel and from deforestation, and a graph depicting the accumulation of CO2 in the atmosphere over time. This simple climate change model was calibrated between years 2000 and 2100 with projections given by two different and extreme emission scenarios from the 2001 IPCC report. Furthermore, the Integrated Science Assessment Model (ISAM) was employed to predict CO2 concentrations in the atmosphere under two emission scenarios. The model calibration parameters are derived from Dutt and Gonzalez (2012). The participants' aim is to maintain the CO2 concentration within the range of 923-953

GtC, which appear on the screen. Participants are asked to achieve the minimum value of the range at the shortest time possible and maintain the CO2 concentration level within the range for the longest time possible. The model was calibrated using two emission scenarios: the "optimistic" and "pessimistic" scenario based on the 2001 IPCC report (Houghton *et al.,* 2001). For details of the basic model calibration, refer to Dutt and Gonzalez (2012).

To avoid extreme emissions policies values of CO2 emissions from fossil fuel and deforestation, they are restricted to realistic emission policies. Total CO2 emissions are the sum of CO2 emissions from fossil fuel and CO2 emissions from deforestation. After participants enter their emission values and click OK the simulation moves forward by two years. During the two years emissions are maintained at the same constant values as initially entered. This procedure is similar to establishing an emission policy that is kept constant for a preset number of years. After the two years, participants are allowed to alter the emissions values based upon current and past CO2 concentration levels. This repeated decision-feedback procedure starts at year 2000 and continues for a total of fifty periods, until the final year (2100) is reached.

4. Experimental design

Participants were randomly assigned to one of four treatments: 1) *slow-no shock*, where the rate of CO2 absorption is 1.2% per year; 2) *rapid-no shock,* where the rate of CO2 absorption is 1.6% per year, 3) *slow- business cycle shock*, where the rate of CO2 absorption is 1.2% per year and there is a moderate and bounded shock causing a temporary reduction in CO2 emissions in year 2030; 4) *rapid- climate tipping event,* where the rate of CO2 absorption is initially 1.6% per year and decreases to 1.2% per year in the last 20 years (after year 2080), due to irreversible climate change that reduces the natural environment's absorption rate.

Participants' goal under all four treatments was to maintain the CO2 Concentration in the Atmosphere within a +/-15 GtC range of the 938 GtC target value. The value of the CO2 target value was intentionally set above the 2000 CO2 concentration of 769 GtC so that the goal is attainable in real-world scenarios. The DCCS-SICC started in year 2000 with an initial CO2 concentration in the atmosphere of 769 GtC, which is the real world value for that year (Houghton *et al.,* 2001). The goal used in the experiment corresponds to the IPCC's "best-case" scenario. It is necessary to make the goal realistically achievable and to account for the practical inability to drastically reduce emissions (Dutt and Gonzalez, 2012).

Thirty-eight undergraduate and graduate students participated in the experiment. Ten participants were randomly assigned to each of treatments one and two and nine participants were randomly assigned to each of treatments three and four. All participants received a bonus point (10% of total course grade), in one course, and an additional bonus point based on their performance in the simulation.

Participants were given instructions before starting the DCCS-SICC. After participants read the instructions and questions were answered, an instructional video was presented that showed what would happen in DCCS-SICC if the status-quo emissions levels were maintained for the duration of the simulation, as well as instructions on the user interface of the DCCS-SICC. The instructional video was based on treatment one, for all participants, and participants did not interact with the simulation. In addition, participants were unaware of which treatment they were playing.

After the instructions, participants were asked to play the DCCS-SICC for 50 decision points over the course of 100 years.

5. Results

5.1 Discrepancy from goal

Participants were generally not performing optimally (Fig. 1), given that the average absolute discrepancy (the absolute discrepancy averaged over all participants and decision points in a condition) was greater than the optimal ("Optimal" is the horizontal line representing the goal value of 938 GtC), in all four treatments. Shapiro-Wilk and Shapiro-Francia W tests failed to reject the null hypothesis of non-normal distributions, in all four treatments. Thus, the distribution of absolute discrepancies in all four treatments is considered non-normal. Furthermore, a nonparametric Kruskal-Wallis test reported that the effect of the different treatments on the absolute value of the discrepancy was significant ($H(3)=11.198, p<0.1$).

As is evident, the average absolute discrepancy of CO2 concentration in the atmosphere was greater when climate dynamics were slow compared to when they were rapid. This is consistent with the literature (Dutt and Gonzalez, 2012) and confirms the hypothesis that participants' control of CO2 concentration in the atmosphere was poorer when the climate dynamics were slow compared to when they were rapid. Furthermore, the absolute discrepancy is greater for the two tipping point scenarios: the business cycle shock and the irreversible climate shock. Of the two tipping point scenarios, the climate shock presents the highest absolute discrepancy, where participants' control is the poorest.

5.2 Learning effects

In all four treatments, the average absolute discrepancy changed significantly over the 50 decision points according to a nonparametric Friedman's ANOVA test (chi-squared (49)=315.88, $p<0.01$; each point in each condition is averaged over all participants in that condition (Dutt and Gonzalez, 2012)). The average absolute discrepancy over the entire time period is presented in Fig. 2. These results suggest that the repeated feedback in DCCS-SICC enabled participants to learn about the dynamics of simulated climate change in all treatments, more so in the *slow-no shock* and *rapid-climate tipping event* treatments. The results also demonstrate the DCCS-SICC as a tool to help participants learn how to stabilize CO2 concentrations.

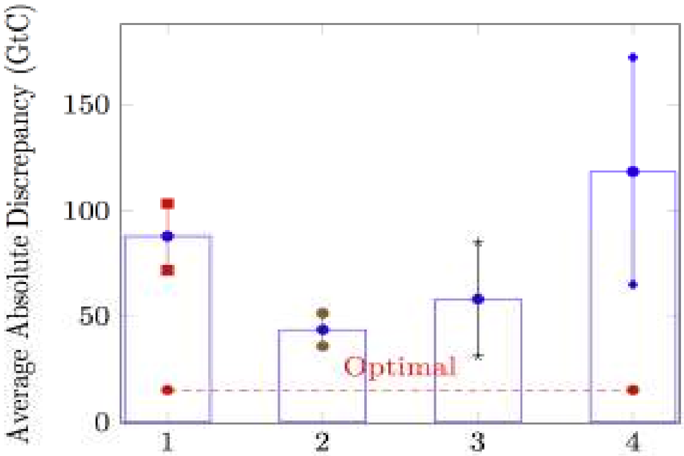

Figure 1: Average Absolute Discrepancy from goal and 90% CI (Treatments: 1) *slow-no shock*, 2) *rapid-no shock,* 3) *slow- business cycle shock*, 4) *rapid- climate tipping event*)

5.3 Time to reach goal and stabilization in goal range

The time it took participants to reach the goal range for the first time and the number of time periods they controlled CO2 concentrations within the goal range were next analyzed (Table 1). Results suggest that there is no significant difference in the year the goal range was reached (*Mean*=2026), however the number of time periods participants were able to stabilize within the goal range differs between treatments. More specifically, the mean time periods in the first treatment (*slow-no shock*) was 6.9 years (SD=1.28), in the second treatment (*rapid-no shock*) was 8.8 years (SD=1.68), in the third treatment (*slow-business cycle shock*) was 10 years (SD=1.58) and in the fourth treatment (*rapid- climate tipping event*) was 4.55 years (SD=2.78). These results suggest that control of climate change is driven by both rate of CO2 absorption and by tipping events. Furthermore, using Dutt and Gonzalez's (2012) definition of "stabilizing at the goal" as the maintenance within the goal range for eight consecutive time periods after they initially came within the goal range would suggest that only the *rapid-no shock* and *slow-business cycle shock* treatments achieved stabilization at the goal.

Table 1. Reaching and stabilizing within the goal range

Treatment	Time to goal	Periods in goal range
slow-no shock	2026.10	6.90
rapid-no shock	2028.70	8.80
slow-business cycle shock	2025.44	10.00
rapid-climate tipping event	2026.11	4.55
Average	2026.63	7.57

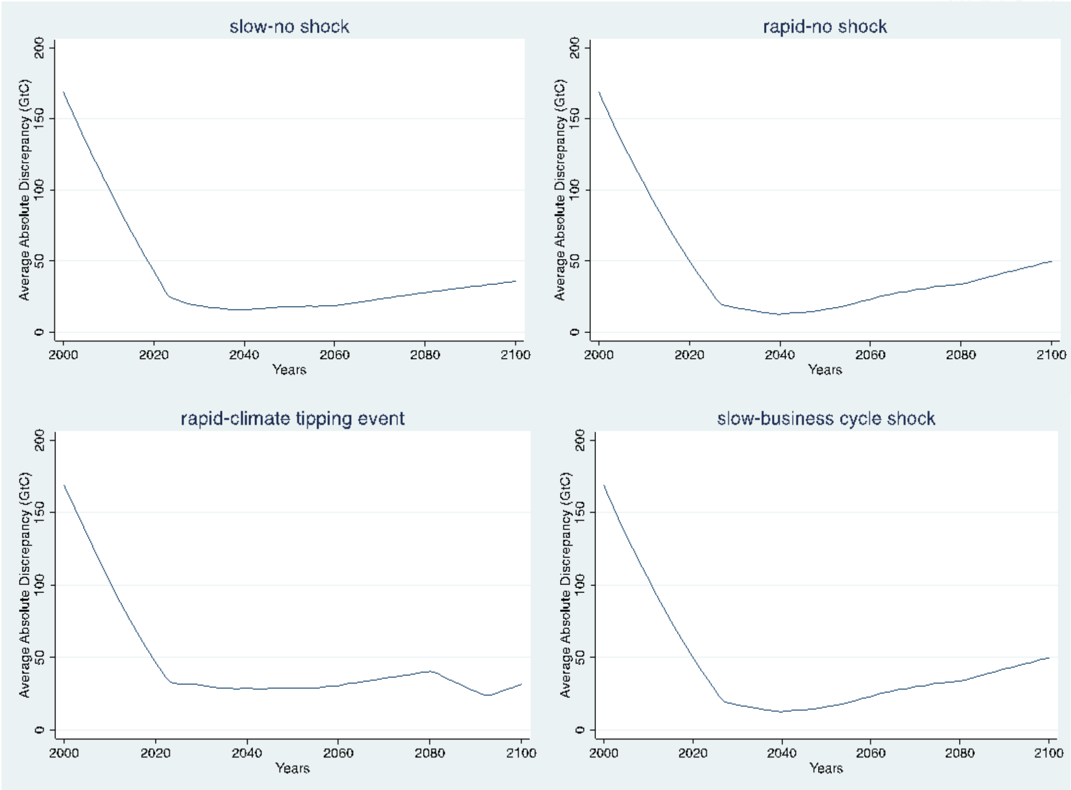

Figure 2: Average absolute discrepancy in CO2 concentration in the atmosphere in the four treatments over 100 years.

5.4 Emissions decision rules

The paper proceeds by analyzing the decision rule used to determine CO2 emissions: CO2 emissions are a function of CO2 concentration and CO2 absorption. Three regression models are employed, following Dutt and Gonzalez (2012), to predict fossil fuel, deforestation and total CO2 emissions in participants' decision-making strategies. The average of the 50 decision points for each participant is employed, resulting in 38 observations. The equations employed in the three models are:

Model 1: Fossil fuel emissions

$$FFE = \beta_0 + \beta_1 D + \beta_2 A + \beta_3 Ratio + \beta_4 R + \beta_5 CD + \beta_6 Tipp + \varepsilon \qquad (10)$$

where

FFE	Fossil fuel CO2 emissions
D	Discrepancy from Goal
A	CO2 concentration
Ratio	Ratio of fossil-fuel emissions to Total emissions
R	CO2 absorption
CD	Climate Dynamics (=0 slow, =1 rapid)

Tipp Tipping event (=1 if business cycle or climate shock)

Model 2: Deforestation emissions

$$DE = \circledR_0 + \circledR_1 D + \circledR_2 A + \circledR_3 Ratio + \circledR_4 R + \circledR_5 CD + \circledR_6 Tipp + \Sigma \tag{11}$$

where *DE* Deforestation CO2 emissions

Model 3: Total emissions

$$TE = \circledR_0 + \circledR_1 D + \circledR_2 A + \circledR_3 Ratio + \circledR_4 R + \circledR_5 CD + \circledR_6 Tipp + \Sigma \tag{12}$$

where *TE* Total CO2 emissions

When CD=0 and Tipp=0, the resulting three models generate predictions for the *slow-no shock* treatment. Thus, values of the predicted betas in the three models are relative to the *slow-no shock* condition. Table 2 provides the OLS regression results for the three models.

According to the results presented in Table 2, all three models exhibit a high adjusted-R^2. The coefficients that are statistically significant in most models are CO2 absorption (R), the Ratio of fossil fuel to total emissions (Ratio), and the dummy variables for Climate Dynamics (CD) and tipping point events (Tipp). Furthermore, all variables consistently maintain their sign across all models, as well as their relative magnitude. In addition, the coefficients that are not statistically significant have the expected sign. Results indicate that an increase of the ratio of fossil fuel emissions to

total emissions reduces all three types of emissions (fossil fuel, deforestation, and total emissions). In other words, participants select to increase deforestation emissions more than fossil fuel emissions when they aim to reduce both types of emissions. In addition, the coefficients that are not statistically significant have the expected sign.

Table 2: Regression output

Model	(1) FFE	(2) DE	(3) TE
D	0.00216 (1.68)	0.000539 (1.86)	0.00270 (1.78)
A	0.00211 (1.89)	0.000481 (1.91)	0.00259 (1.97)
R	0.769*** (5.85)	0.138*** (4.66)	0.908*** (5.86)
Ratio	-6.581** (-3.51)	-9.759*** (-23.08)	-16.34*** (-7.41)
CD	-0.454*** (-3.95)	-0.0744** (-2.87)	-0.528*** (-3.90)
Tipp	0.150* (2.28)	0.0249 (1.67)	0.175* (2.26)
Constant	7.164* (2.72)	8.453*** (14.19)	15.62*** (5.03)
R^2	0.914	0.990	0.955
Adjusted R^2	0.897	0.987	0.946
F	54.74***	488.1***	108.5***

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Regarding the dummy variables of Climate Dynamics (CD) and Tipping events (Tipp), it is clear from all three models that the coefficients are statistically significant and maintain the same sign in all three regressions. Thus, the presence of rapid climate dynamics reduces all emissions levels and the existence of a tipping event increases all emissions levels selected by participants. Furthermore, the magnitude of the CD coefficient compared to the Tipp coefficient suggests that Climate Dynamics play a more significant role when comparing their individual effects on fossil fuel emissions, deforestation emissions and total emissions.

6. Conclusions

The aim of the present paper was to investigate the reasons for participants' poor control over dynamic systems in the context of climate change and to discover possibilities in which these problems can be overcome. First, a simplified dynamic programming problem of climate change with stochastic and irreversible climate change was developed, that incorporated tipping points arising from business cycle shocks and climate change tipping events. Second, a simplified simulation user interface was developed, the dynamic climate change simulator with stochastic and irreversible climate change (DCCS-SICC). DCCS-SICC was employed to investigate participants' ability to control climate change under different conditions of climate dynamics and tipping events.

Results indicate that a change in climate dynamics from slow to rapid improved participants' control of CO2 concentration. However, the change in climate dynamics does not suffice to improve participants' control of CO2 concentration, if other factors come into play. For example, the presence of tipping events may cancel out the performance improvement due to climate dynamics as is evident from our results.

Participants' control of CO2 concentration deteriorated significantly when faced with a climate tipping event, compared to a single business cycle shock, even though climate dynamics were rapid in the first treatment compared to the second one. Furthermore, evidence suggests that the presence of rapid climate dynamics reduces emissions levels and the existence of a tipping event increases emissions levels. Finally, climate dynamics play a more significant role compared to the tipping events analyzed in the simulation.

Future work on individual agents' control of climate change should be directed towards repeated performances in DCCS-SICC. The literature on dynamic decision making suggest participants' initial performance in interactive management flight simulators is initially quite poor but improves with repeated performances. The repeated performances would be of particular interest if participants were switched between the four treatments, thus on the one hand developing a generic understanding, but on the other having to continuously improve and reevaluate their generic understanding of CO2 accumulation when faced with stochastic and irreversible climate change. A more realistic model can be further achieved where individuals cannot directly control CO2 emissions but only indirectly through relevant policies would make the simulation more realistic, for example controlling taxes.

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On the dynamic linkages between CO_2 emissions, energy consumption and growth in Greece

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Abstract
This paper attempts to analyze the short- and long-run causality issues between energy consumption, CO_2 emissions, and economic growth in Greece using time-series techniques. To this end, annual data covering the period 1960–2012 are employed and tests for unit roots, ARDL-bounds testing approach of cointegration, and Granger-causality based on error-correction models are applied. The results reveal strong bi-directional causal impacts in the long-run between carbon dioxide emissions and energy consumption while per capita GDP growth behavior seems rather exogenous. For the short-run there is evidence of two-way causality in all examined pairs with only exception the direction CO_2 towards GDP.

Keywords: CO_2 emissions; energy consumption; growth; causality; Greece.

Δυναμική αλληλεξάρτηση μεταξύ εκπομπών CO_2, ενέργειας και οικονομικής ανάπτυξης: Μία οικονομετρική διερεύνηση για την περίπτωση της Ελλάδας

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ΕΙΣΑΓΩΓΗ

Στην προηγούμενη δεκαετία, έχουν εκπονηθεί πολυάριθμες μελέτες που εξετάζουν τη σταδιακή εξέλιξη της σχέσης μεταξύ της περιβαλλοντικής ποιότητας και του επιπέδου ΑΕΠ για μια χώρα ή μια ομάδα χωρών. Τέτοιες μελέτες χαρακτηρίζονται ως περιβαλλοντικές αναλύσεις καμπυλών Kuznets, λόγω μιας υπόθεσης που διατύπωσε το 1955 ο Simon Kuznets. Η αιτιώδης σχέση μεταξύ της περιβαλλοντικής ποιότητας και του επιπέδου ανάπτυξης είναι συγκεκριμένης φοράς · από την ανάπτυξη προς τις εκπομπές ρύπων και κατά συνέπεια προς την περιβαλλοντική ποιότητα. Ωστόσο, έχει επίσης υποστηριχτεί ότι αυξημένα επίπεδα εκπομπών λόγω της οικονομικής ανάπτυξης μπορεί να έχουν επιβλαβή αποτελέσματα στις δυνατότητες παραγωγής (Pearson, 1994; Stern et al., 1994). Κατά συνέπεια, η αιτιώδης σχέση ανάμεσά τους μπορεί να είναι αμφίδρομη.

Ως εκ τούτου, οι αναλύσεις αιτιότητας αποτελούν όχι μόνο προϋποθέσεις για την περαιτέρω έρευνα στη σχέση "περιβαλλοντική ποιότητα - ΑΕΠ" αλλά και τα αποτελέσματά τους μπορεί επίσης να έχουν σοβαρές επιπτώσεις στις πολιτικές αποφάσεις. Παραδείγματος χάριν, εάν δεν υπάρχει καμία αιτιότητα, μπορεί οι πολιτικές για τη μείωση των εκπομπών να μην έχουν καθόλου επιπτώσεις στην οικονομική ανάπτυξη. Εντούτοις, εάν υφίσταται οποιαδήποτε αιτιότητα, τα πολιτικά μέτρα πρέπει να σχεδιαστούν με τη σαφή συνειδητοποίηση της κατεύθυνσης της αιτιώδους σχέσης μεταξύ των εκπομπών και του ΑΕΠ. Οι αναλύσεις αιτιότητας έχουν εφαρμοστεί σε πολλές εμπειρικές μελέτες, ερευνώντας είτε την αιτιώδη σχέση μεταξύ της κατανάλωσης ενέργειας και του εισοδηματικού επιπέδου (π.χ. Yang, 2000 Shiu και Lam, 2004 Yoo, 2005) είτε την αιτιώδη σχέση μεταξύ εκπομπών CO_2 και εισοδηματικού επιπέδου. Σε μια μελέτη που πραγματοποιήθηκε από τους Coondoo και Dinda (2002), βρέθηκε μονόδρομη αιτιώδης σχέση μεταξύ των εκπομπών CO_2 και του εισοδήματος που αφορά τις αναπτυγμένες ομάδες χωρών Βόρειας Αμερικής καθώς και Ανατολικής και Δυτικής Ευρώπης.

Ένας σημαντικός αριθμός μελετών για την εξέλιξη της σχέσης μεταξύ της οικονομικής ανάπτυξης και της περιβαλλοντικής ρύπανσης έχει εστιάσει στη σχέση μεταξύ της οικονομικής μεγέθυνσης και της ενεργειακής κατανάλωσης, δεδομένου ότι οι εκπομπές ρύπανσης παράγονται πρώτιστα με την κατανάλωση στερεών καυσίμων. Είναι λοιπόν προφανές ότι η κατανόηση των αλληλεπιδράσεων και της κατεύθυνσης της αιτιότητας μεταξύ της κατανάλωσης ενέργειας και οικονομικής ανάπτυξης είναι πολύ σημαντική στη διαμόρφωση των πολιτικών για την ενέργεια και το περιβάλλον.

Και για τις δύο προαναφερθείσες διμεταβλητές σχέσεις, στη συναφή βιβλιογραφία εξετάζονται οι ακόλουθες υποθέσεις :

(1) The “growth” hypothesis: Θεωρεί ότι η φορά της αιτιώδους έχει κατεύθυνση από την κατανάλωση ενέργειας/ εκπομπές ρύπων προς το εισόδημα.

(2) The “conservation” hypothesis: Θεωρεί ότι η φορά της αιτιώδους έχει κατεύθυνση από το εισόδημα προς την κατανάλωση ενέργειας / εκπομπές ρύπων.

(3) The “neutrality” hypothesis: Θεωρεί ότι υπάρχει απουσία αιτιωδών επιδράσεων μεταξύ εισοδήματος και κατανάλωσης ενέργειας/ εκπομπών ρύπων. Και τέλος

(4) The “feedback” hypothesis: Θεωρεί ότι υπάρχει αμφίδρομη αιτιώδης επίδραση μεταξύ εισοδήματος και κατανάλωσης ενέργειας/ εκπομπών.

Η βιβλιογραφία δεν έχει καταλήξει ακόμα σε μια γενική αποδοχή για την φύση-κατεύθυνση της αιτιώδους σχέσης μεταξύ της κατανάλωσης ενέργειας, ρύπων και της οικονομικής ανάπτυξης διότι τα αποτελέσματα διαφοροποιούνται αναλόγως του επιπέδου ανάπτυξης, της εξεταζόμενης χρονικής περιόδου αλλά και της εφαρμοζόμενης εμπειρικής μεθοδολογίας. Η σύνδεση των δύο βιβλιογραφιών (CO_2-Growth nexus και Energy Consumption-Growth nexus), έτσι ώστε η σχέση μεταξύ της οικονομικής ανάπτυξης, της κατανάλωσης ενέργειας και των εκπομπών ρύπανσης να μπορεί να εξετάζεται μέσα σε ένα πολυμεταβλητό πλαίσιο αιτιότητας, είναι μια σχετικά νέα περιοχή της συναφούς έρευνας. Πολιτικές που στοχεύουν να περιορίσουν βαθμιαία τις εθνικές ενεργειακές ανάγκες οφείλουν να εξετάσουν τα πιθανά «causal linkages» μεταξύ της οικονομικής ανάπτυξης, της κατανάλωσης ενέργειας και της επιβάρυνσης του περιβάλλοντος.

Οι περισσότερες υπάρχουσες μελέτες αφορούν μεμονωμένες χώρες. Υπάρχουν μελέτες για τις αναπτυγμένες χώρες, όπως Γαλλία (Ang, 2007) και ΗΠΑ (Soytas et al., 2007), για αναπτυσσόμενες χώρες, όπως Κίνα (Zhang & Cheng, 2009), Μαλαισία(Ang, 2008) και Τουρκία (Halicioglu, 2009; Soytas & Sari, 2009) και για τις πλούσιες πετρελαϊκές χώρες του OPEC (Sari & Soytas, 2009). Οι Apergis and Payne (2009), εξετάζουν ένα panel από χώρες της Κεντρικής Αμερικής ενώ οι Lean and Smyth για ένα panel από 5 Ασιατικές χώρες. Τα αποτελέσματα των ερευνών εξακολουθούν να είναι ανάμικτα.

Στην περίπτωση της Ελλάδας, αν και διάφορες μελέτες έχουν εξετάσει τη σχέση μεταξύ της ενεργειακής χρήσης και της οικονομικής ανάπτυξης, μόνο λίγες έχουν ερευνήσει αυτήν τη σχέση με βάση τις πιο σύγχρονες οικονομετρικές προσεγγίσεις (π.χ. με συνολοκλήρωση) και κυρίως σε ένα διευρυμένο πλαίσιο που να περιλαμβάνει και τις περιβαλλοντικές επιδράσεις.

Ο Hondroyiannis et al. [2002] εξέτασαν την εμπειρική σχέση μεταξύ της κατανάλωσης ενέργειας και της οικονομικής ανάπτυξης την περίοδο 1960-1996. Οι Rapanos και Polemis [2005] ανέλυσαν την αιτιώδη σχέση μεταξύ του ΑΕΠ και της κατανάλωσης ενέργειας, για τη χρονική περίοδο1965-1998. Οι Papadopoulos και Haralambopoulos [2006] ερεύνησαν εάν οι μεταβολές των εκπομπών άνθρακα συσχετίζονται με τις αλλαγές της ενεργειακής έντασης, των τιμών και της κατανάλωσης ενέργειας. Υπάρχει μια πολυδιάστατη ανάγκη κατανόησης της ενεργειακής κατάστασης στην Ελλάδα, για την διαμόρφωση νέων απόψεων στη σχέση μεταξύ της οικονομικής ανάπτυξης, της ενεργειακής έντασης και των εκπομπών του CO_2.

Ο σκοπός αυτής της εργασίας είναι, με τη χρησιμοποίηση των Ελληνικών στοιχείων, να εξεταστεί η σχέση μεταξύ της οικονομικής ανάπτυξης, της ενεργειακής έντασης και των εκπομπών του CO_2. Η ανάλυση αιτιότητας θα πραγματοποιηθεί με την εφαρμογή των οικονομετρικών ελέγχων της κατά Granger αιτιότητας. Κατ' αρχάς, εξετάζονται η στασιμότητα και η ύπαρξη συνολοκλήρωσης μεταξύ των χρονικών σειρών των εκπομπών CO_2 και του πραγματικού ΑΕΠ. Ανάλογα με τα αποτελέσματα, προχωρούμε στην εκτίμηση ενός υποδείγματος διόρθωσης σφάλματος (ECM) και εξετάζουμε για αιτιότητα κατά Granger στη μακροχρόνια και βραχυχρόνια περίοδο.

ΤΟ ΠΡΩΤΟΚΟΛΛΟ ΤΟΥ ΚΥΟΤΟ

Το Πρωτόκολλο του Kyoto προέκυψε από τη Σύμβαση-Πλαίσιο για τις Κλιματικές Αλλαγές που είχε υπογραφεί στη Διάσκεψη του Rio, τον Ιούνιο του 1992, από το σύνολο σχεδόν των κρατών (η Ελλάδα κύρωσε τη Σύμβαση αυτή, κάνοντάς την νόμο του Κράτους τον Απρίλιο του 1994). Στόχος της Σύμβασης είναι "η σταθεροποίηση των συγκεντρώσεων των αερίων του θερμοκηπίου στην ατμόσφαιρα, σε επίπεδα τέτοια ώστε να προληφθούν επικίνδυνες επιπτώσεις στο κλίμα από τις ανθρώπινες δραστηριότητες".

Το 1997, στο Kyoto, εκατό χώρες, κυρίως του Βορρά, συμφώνησαν να μειώσουν τις εκπομπές των αερίων του θερμοκηπίου στο 5,2% κάτω από τα επίπεδα του 1990 μέσα σε 15 χρόνια (ή του 1995 για ορισμένα αέρια) κατά τη διάρκεια της πρώτης «περιόδου δέσμευσης», η οποία καλύπτει τα έτη 2008 έως 2012. Αλλά η Κίνα και η Ινδία, οι οποίες έχουν το γρηγορότερο ρυθμό ανάπτυξης όσον αφορά τη μόλυνση, δεν συμπεριλαμβάνονταν στη συμφωνία. Αναφέρεται ότι προτιμήθηκε ο καθορισμός πενταετούς περιόδου δέσμευσης αντί στόχου ενός έτους για να εξομαλυνθούν οι ετήσιες διακυμάνσεις των εκπομπών αερίων που οφείλονται σε ανεξέλεγκτους παράγοντες, όπως ο καιρός. Αυτή η συμφωνία δεν επαρκούσε για να ικανοποιήσει την πρώτη προϋπόθεση της Συνδιάσκεψης του Rio, να σταθεροποιήσει δηλαδή τις συγκεντρώσεις των αερίων στην ατμόσφαιρα. Επίσης, σε κάθε χώρα δόθηκε μια ποσόστωση που βασιζόταν στα τρέχοντα επίπεδα των εκπομπών αερίων (με τίτλο grandfathering). Αυτό παραβίαζε κατάφωρα τη δεύτερη απαίτηση της Συνδιάσκεψης του Rio, για την ισότητα, αφού όσο μεγαλύτερη ζημιά είχε προκαλέσει μια χώρα στο παρελθόν τόσο περισσότερο θα της επιτρεπόταν να μολύνει στο μέλλον. Τελικά, το Πρωτόκολλο του Kyoto υπογράφηκε από 178 χώρες, οι οποίες αντιπροσωπεύουν το 95,7% του πληθυσμού του πλανήτη.

Τα αέρια που πραγματεύεται το Πρωτόκολλο του Kyoto είναι έξι:

- διοξείδιο του άνθρακα CO_2 (που αποτελεί το σημαντικότερο αέριο),
- μεθάνιο CH_4,
- υποξείδιο του αζώτου N_2O,
- υδροφθοράνθρακες HFC,
- πλήρως φθοριωμένοι υδρογονάνθρακες ή υπερφθοράνθρακες PFC και εξαφθοριούχο θείο SF_6.

Ωστόσο, σύμφωνα με έρευνα που επιμελήθηκαν το JRC και η Υπηρεσία Περιβαλλοντικής Αξιολόγησης της Ολλανδίας με τίτλο “Μακροπρόθεσμες τάσεις στις παγκόσμιες εκπομπές CO_2” οι παγκόσμιες εκπομπές διοξειδίου του άνθρακα αυξήθηκαν κατά 45% μεταξύ 1990 και 2010, αγγίζοντας το πρωτοφανές επίπεδο των 33 δισεκατομμυρίων τόνων, όπως αναφέρεται σε έρευνα του Κοινού Κέντρου Ερευνών της Ευρωπαϊκής Ένωσης (Joint Research Centre – JRC). Και μάλιστα πρέπει να επισημανθεί ότι σήμερα η ανάπτυξη των ανανεώσιμων πηγών ενέργειας, των πυρηνικών και η βελτίωση της ενεργειακής αποδοτικότητας δεν επαρκούν για να καλύψουν τη ζήτηση ενέργειας για ηλεκτροπαραγωγή και μεταφορές, ιδίως στις αναπτυσσόμενες χώρες.

Εμπειρική Ανάλυση

Δεδομένα

Στα πλαίσια της εμπειρικής ανάλυσης χρησιμοποιήθηκαν στοιχεία για την Ελλάδα από την World Bank Database που καλύπτουν την χρονική περίοδο 1980-2010 . Ειδικότερα, συλλέχθηκαν ετήσια στοιχεία για το πραγματικό κατά κεφαλήν ΑΕΠ σε Ευρώ (YRPCE), τις κατά κεφαλήν εκπομπές CO_2 σε μετρικούς τόνους (COPC) και την κατά κεφαλή χρήση ενέργειας σε kg (EUPC).

Μεθοδολογία και αποτελέσματα της εμπειρικής ανάλυσης

Η ύπαρξη χρονολογικών σειρών δημιουργεί την ανάγκη για έλεγχο στασιμότητας, καθώς τα γνωστά κριτήρια αξιολόγησης και ελέγχου της σημαντικότητας των οικονομετρικών υποδειγμάτων είναι αξιόπιστα μόνο όταν υπάρχει στασιμότητα των σειρών (πρόβλημα πλασματικής παλινδρόμησης). Γενικότερα οι μεταβλητές θα πρέπει να διακρίνονται από σταθερότητα των μέσων και των διακυμάνσεων στο χρόνο. Έτσι, στο πρώτο βήμα της εμπειρικής ανάλυσης, γίνεται η διαπίστωση των χαρακτηριστικών ολοκλήρωσης των εξεταζόμενων μεταβλητών. Για τον έλεγχο στασιμότητας χρησιμοποιήθηκαν ο επαυξημένος έλεγχος των Dickey-Fuller (ADF test) καθώς και ο έλεγχος των Elliot, Rothenberg and Stock γνωστός ως ADF-GLS ο οποίος είναι νεότερης γενιάς και υψηλότερης στατιστικής δύναμης. Τα αποτελέσματά τους, για όλες τις μεταβλητές μας στο επίπεδό τους και σε μορφή πρώτων διαφορών και χρησιμοποιώντας σταθερό όρο και χρονική τάση στην στατιστική ελέγχου, φαίνονται στον ακόλουθο Πίνακα 1.

Πίνακας 1: Έλεγχοι Μοναδιαίας Ρίζας			
VARIABLE	ADF	ADF-GLS	CONCLUSION
LCOPC	-1.1759 (-3.5023)	-0.2938 (-3.19)	NON-STATIONARY
LEUPC	-1. 6312 (-3.4986)	-0.5564 (-3.1868)	NON-STATIONARY
LYRPCE	-2.4153 (-3.5577)	-2.1157 (-3.1900)	NON-STATIONARY
DLCOPC	-8.0437 (-3.5043)	-7.507288 (-3.1900)	STATIONARY
DLEUPC	-5.5781 (-3.5004)	-5.6918 (-3.1868)	STATIONARY
DLYRPCE	-2.1392 (-3.5577)	-3.2931 (-3.2120) *	STATIONARY

Από την σύγκριση με την κριτική τιμή του ελέγχου διαπιστώνεται ότι οι σειρές είναι μη στάσιμες πρώτης τάξης. Επομένως, το επόμενο βήμα θα είναι ο έλεγχος για ύπαρξη συνολοκλήρωσης μεταξύ τους, προκειμένου να ανιχνεύσουμε την πιθανή παρουσία μακροχρόνιων και βραχυχρόνιων αιτιωδών κατά Granger επιδράσεων μεταξύ τους. Για τις ανάγκες της δικής μας έρευνας, δεδομένου ότι αφενός ο αριθμός των παρατηρήσεων δεν είναι ιδιαίτερα υψηλός για να ταυτοποιήσουμε τα χαρακτηριστικά ολοκλήρωσης των σειρών που εξετάζουμε και αφετέρου η πιθανή πλασματική εικόνα της μακροχρόνιας σχέσης μεταξύ τους λόγω της παρουσίας σημαντικών διαρθρωτικών αλλαγών, μας κατεύθυνε στην υιοθέτηση της μεθοδολογίας συνολοκλήρωσης ARDL (Pesaran, 2001). Η συγκεκριμένη μεθοδολογία εξοικονομεί βαθμούς ελευθερίας και οδηγεί σε πιο αξιόπιστα συμπεράσματα επειδή είναι τεχνική συνολοκλήρωσης μιας εξίσωσης και δεν απαιτεί προγενέστερο έλεγχο στασιμότητας των εξεταζόμενων σειρών για να επιβεβαιωθεί ότι είναι μη στάσιμες ίδιας τάξης ολοκλήρωσης.

Η μέθοδος ARDL επιτρέπει την εκτίμηση της μακροχρόνιας σχέσης με απλή OLS. Για ένα υπόδειγμα που έστω περιλαμβάνει τις χρονολογικές σειρές Y_t, X_t και Z_t, αρχικά γίνεται η εκτίμηση του ακόλουθου *υπό συνθήκη υποδείγματος διόρθωσης λαθών* με OLS:

$$\Delta Y_t = a_0 + \gamma_1 Y_{t-1} + \gamma_2 X_{t-1} + \gamma_3 Z_{t-1} + \sum_{i=1}^{n} \beta_{1,i} \Delta Y_{t-i} + \sum_{i=1}^{n} \beta_{2,i} \Delta X_{t-i} + \sum_{i=1}^{n} \beta_{3,i} \Delta Z_{t-i} + u_t \quad \textbf{(1)}$$

όπου a_0 είναι ο σταθερός όρος, γ είναι οι μακροχρόνιοι πολλαπλασιαστές και β είναι οι βραχυχρόνιοι συντελεστές. Το υπόδειγμα (1) είναι δυνατό να περιλαμβάνει και προσδιοριστικές μεταβλητές όπως χρονική τάση, ψευδομεταβλητές και άλλες εξωγενείς μεταβλητές με σταθερό αριθμό υστερήσεων.

Στη συνέχεια, ελέγχουμε τις υποθέσεις

$$\begin{aligned} H_0 &: \gamma_1 = \gamma_2 = \gamma_3 = 0 \\ H_1 &: \gamma_1 \neq 0, \gamma_2 \neq 0, \gamma_3 \neq 0 \end{aligned} \quad \textbf{(2)}$$

Απόρριψη της μηδενικής, ότι δηλαδή οι παράμετροι των μεταβλητών στα επίπεδά τους και με μια χρονική υστέρηση είναι στατιστικά μηδέν, συνεπάγεται ύπαρξη συνολοκλήρωσης μεταξύ των μεταβλητών. Για τον έλεγχο της μηδενικής υπόθεσης υπολογίζεται μια τροποποιημένη F στατιστική (FPSS), της οποίας όμως η ασυμπτωτική κατανομή δεν ακολουθεί τη συνήθη F κατανομή.

Πίνακας 2: Έλεγχοι Συνολοκλήρωσης		
Model	**F-statistic**	**Conclusion**
LYRPC\LCOPC,LEUPC	4.5493	Inconclusive
LCOPC\LYRPC,LEUPC	7.2801	Long-run causality
LEUPC\LCOPC,LYRPC	4.4265	Inconclusive
NOTE: 90% Lower Bound 95% Upper Bound 90% Lower Bound 90% Upper Bound 4.3867 5.6666 3.5115 4.6144		

Στον παραπάνω Πίνακα 2, εμφανίζονται τα αποτελέσματα των ελέγχων συνολοκλήρωσης για όλες τις εξεταζόμενες σχέσεις. Παρατηρούμε ότι το αποτέλεσμα του ελέγχου είναι αβέβαιο όταν εξαρτημένη μεταβλητή είναι το εισόδημα ή η κατανάλωση ενέργειας. Εάν απορριφθεί η μηδενική της μη ύπαρξης μακροχρόνιας σχέσης μεταξύ των μεταβλητών ή ακόμη και αν το αποτέλεσμα του ελέγχου είναι αβέβαιο, το επόμενο βήμα είναι η επιλογή του άριστου ARDL υποδείγματος το οποίο προσαρμόζεται καλύτερα στα δεδομένα με βάση κριτήρια επιλογής όπως το Akaike-AIC ή το Schwarz-SBC. Μια γενική μορφή του υποδείγματος είναι

$$Y_t = \beta_0 + \sum_{i=1}^{p} \beta'_{1,i} Y_{t-i} + \sum_{i=0}^{q} \beta'_{2,i} X_{t-i} + \sum_{i=0}^{r} \beta'_{3,i} Z_{t-i} + \varepsilon_t \qquad \textbf{(3)}$$

όπου p, q, r είναι οι χρονικές υστερήσεις.

Από το εκτιμημένο υπόδειγμα (3) προκύπτουν οι μακροχρόνιοι συντελεστές χρησιμοποιώντας μη γραμμικές συναρτήσεις των εκτιμημένων συντελεστών της (3):

$$a_0 = \frac{\beta'_0}{1-\sum_{i=1}^{p} \beta'_{1,i}} \qquad a_1 = \frac{\sum_{i=0}^{q} \beta'_{2,i}}{1-\sum_{i=1}^{p} \beta'_{1,i}} \qquad a_2 = \frac{\sum_{i=0}^{r} \beta'_{3,i}}{1-\sum_{i=1}^{p} \beta'_{1,i}} \qquad \textbf{(4)}$$

όπου a_0 είναι ο σταθερός όρος και a_1, a_2 είναι οι μακροχρόνιοι συντελεστές κλίσης. Θεωρώντας, όπως προαναφέρθηκε ότι είναι πιθανή η παρουσία μακροχρόνιων αιτιωδών σχέσεων και προς τις τρείς κατευθύνσεις, παρουσιάζουμε στον ακόλουθο Πίνακα 3, τις εκτιμήσεις των αντίστοιχων μακροχρόνιων σχέσεων ισορροπίας.

Πίνακας 3: Εκτιμήσεις των μακροχρόνιων συντελεστών (Long run estimates)			
Independent Variables	Dependent Variables		
	Estimated coefficients (prob-value)		
	LRYPC	LCOPC	LEUPC
LRYPC	-	-0.2139[.008]	0.3426[.001]
LCOPC	-2.0215 [0.028]	-	1.2089[.000]
LEUPC	1.9650 [0.011]	0.8766[.000]	-
constant	-1.5362 [0.680]	-2.7000[.006]	2.0054[.033]

Πέρα από την μακροχρόνια σχέση ισορροπίας που συνδέει τις τρεις μεταβλητές Y_t, X_t και Z_t, είναι δυνατό βραχυχρόνια να βρίσκονται σε ανισορροπία. Αυτή η δυναμική της βραχυχρόνιας σχέσης μπορεί να διατυπωθεί στο πλαίσιο ενός *υποδείγματος διόρθωσης λαθών* (Error Correction Model – ECM) το οποίο στην ουσία συνδέει τη μακροχρόνια με τη βραχυχρόνια συμπεριφορά των μεταβλητών. Στο προτελευταίο αυτό βήμα της μεθόδου ARDL γίνεται εκτίμηση των βραχυχρόνιων δυναμικών συντελεστών, εξειδικεύοντας το αντίστοιχο, για το άριστο ARDL, υπόδειγμα διόρθωσης λαθών με την παρακάτω γενική μορφή:

$$\Delta Y_t = \delta_0 + \lambda \hat{u}_{t-1} + \sum_{i=1}^{r} \delta_{1,i} \Delta Y_{t-i} + \sum_{i=1}^{n} \delta_{2,i} \Delta X_{t-i} + \sum_{i=1}^{r} \delta_{3,i} \Delta Z_{t-i} + e_t \quad \textbf{(5)}$$

όπου το $\hat{u}_{t-1}$ είναι ο *όρος διόρθωσης λαθών* που προκύπτει από τη μακροχρόνια σχέση ισορροπίας και η παράμετρος λ είναι ο *συντελεστής προσαρμογής*, που δείχνει την ταχύτητα με την οποία αποκαθίσταται η ισορροπία της Y_t μετά από μια πιθανή εξωγενή διαταραχή (shock).

Στο τελευταίο βήμα της μεθοδολογίας συνολοκλήρωσης ARDL είναι δυνατός και ο *έλεγχος αιτιότητας κατά Granger* (Granger, 1969) ανάμεσα στις μεταβλητές. Στον Πίνακα 4 που ακολουθεί, παρουσιάζονται τα υποδείγματα διόρθωσης σφάλματος σε συνδυασμό με τα αποτελέσματα α) των στατιστικών ελέγχου Wald X^2 για την ανίχνευση σημαντικών βραχυχρόνιων επιδράσεων μεταξύ των εξεταζόμενων σειρών σε μορφή πρώτων διαφορών όπως και της κατεύθυνσης των αιτιωδών επιδράσεων και β) της στατιστικής t για τον έλεγχο σημαντικότητας του όρου διόρθωσης σφάλματος και της κατεύθυνσης των μακροχρόνιων αιτιωδών επιδράσεων.

Πίνακας 4: Εκτιμήσεις υποδειγμάτων διόρθωσης σφάλματος (Error correction models)

Independent Variables	Dependent Variables Test-Value [prob-value]		
	DLRYPC	DLCOPC	DLEUPC
Lags of DLRYPC	-	X^2= 110.0391[.000]	X^2= 12.4741[.029]
Lags of DLCOPC	X^2 = 3.3508[.067]	-	X^2= 49.6212[.000]
Lags of DLEUPC	X^2= 12.0198[.035]	X^2= 74.3298[.000]	-
ECT(-1)	t = -3.1594[.006]	t = -3.1569[.007]	t = -2.9604[.010]

Τα αποτελέσματα του Πίνακα 4, συνοψίζονται στο παρακάτω γράφημα με τα εξωτερικά βέλη να προσδιορίζουν την αμφίδρομη (για όλα τα ζεύγη των μεταβλητών όπως ανιχνεύθηκε) μακροχρόνια αιτιώδη επίδραση, ενώ τα εσωτερικά βέλη με το ασυνεχές περίγραμμα να απεικονίζουν τις βραχυχρόνιες αιτιώδεις επιδράσεις οι οποίες είναι επίσης αμφίδρομες με εξαίρεση την σχέση μεταξύ ρύπων και ΑΕΠ όπου φαίνεται πως η επίδραση είναι μονόδρομη και συγκεκριμένα είναι από το ΑΕΠ προς τους περιβαλλοντικούς ρύπους.

Συμπεράσματα

Σύμφωνα με τα αποτελέσματα βρέθηκε μακροχρόνια αιτιότητα με κατεύθυνση από την κατανάλωση ηλεκτρικής ενέργειας στην οικονομική ανάπτυξη, γεγονός που χαρακτηρίζει οικονομίες που εξαρτώνται από την ενέργεια.

Μια αύξηση της κατανάλωσης ηλεκτρικής ενέργειας οδηγεί σε υψηλότερο ΑΕΠ διότι, εκτός από το άμεσο αποτέλεσμα που αφορά την ενέργεια που ζητείται και καταναλώνεται για εμπορική χρήση και δημιουργεί υψηλότερη μεγέθυνση της οικονομίας, η υψηλή κατανάλωση ηλεκτρικής ενέργειας δημιουργεί περαιτέρω αύξηση παραγωγής ενέργειας, η οποία εμμέσως δημιουργεί απασχόληση και υποδομές στον τομέα των υπηρεσιών ενέργειας.

Τα αποτελέσματα δείχνουν επίσης ότι η υποβάθμιση του περιβάλλοντος έχει θετική σχέση με την οικονομική ανάπτυξη μακροπρόθεσμα. Αυτό οφείλεται στις εκπομπές ρύπων κατά τη διαδικασία παραγωγής και αντανακλά την εμπειρία πολλών βιομηχανικών χωρών. Φυσικά, αυτό δεν υπονοεί ότι η περιβαλλοντική υποβάθμιση είναι η ενδεδειγμένη πορεία για την προώθηση της οικονομικής ανάπτυξης. Άλλωστε, με βάση την σχετική βιβλιογραφία για τη βιωσιμότητα, επίκεντρο της πολιτικής του κράτους πρέπει να είναι η κοινωνική ευημερία και όχι μόνο το κατά κεφαλήν εισόδημα. (Gowdy, 2004, 2005).

Επιπρόσθετα, μια συνεχιζόμενη υποβάθμιση της ποιότητας του περιβάλλοντος μπορεί να δημιουργήσει αρνητικές εξωτερικότητες για την οικονομία μέσω της μείωσης της υγείας του ανθρώπινου κεφαλαίου και, κατά συνέπεια και της παραγωγικότητας μακροπρόθεσμα (Ang, 2008) .

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Διαστήματα εμπιστοσύνης για εκατοστημόρια σε στάσιμες ARMA διαδικασίες: Μία εμπειρική εφαρμογή σε περιβαλλοντικά δεδομένα[34]

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Περίληψη
Η εκτίμηση εκατοστημορίων παίζει πλέον σημαντικό ρόλο στα διάφορα στάδια λήψης αποφάσεων σε πολλούς επιστημονικούς τομείς. Όμως η μέχρι τώρα έρευνα ανάπτυξης μεθόδων εκτίμησης των εκατοστημορίων βασίστηκε στην υπόθεση ότι οι παρατηρήσεις στο δείγμα διαμορφώνονται ανεξάρτητα μεταξύ τους. Στην παρούσα εργασία καταργούμε την υπόθεση αυτή υποθέτοντας ότι οι τιμές της υπό μελέτη μεταβλητής σχηματίζονται με βάση την γενική γραμμική στοχαστική ανέλιξη. Εξάγοντας πρώτα την ασυμπτωτική κατανομή του εκτιμητή μεγίστης πιθανοφάνειας για το $100\times P_{th}$ εκατοστημόριο, δίνουμε στη συνέχεια τη γενική μορφή του αντίστοιχου ασυμπτωτικού διαστήματος εμπιστοσύνης. Η εγκυρότητα του διαστήματος αυτού όταν εκτιμάται σε στάσιμες σειρές AR(1) και ARMA(1,1) εξετάζεται μέσω χρήσης προσομοιώσεων Monte-Carlo και υπολογισμού δυο στατιστικών κριτηρίων: (α) του πραγματικού επιπέδου εμπιστοσύνης, και (β) του αναμενόμενου ημι-πλάτους του διαστήματος ως ποσοστό της πραγματικής τιμής του εκατοστημορίου. Τα αποτελέσματα των πειραμάτων προσομοίωσης δείχνουν ότι η εγκυρότητα του εκτιμηθέντος ασυμπτωτικού διαστήματος εμπιστοσύνης εξαρτάται από το μέγεθος του δείγματος, το μέγεθος του συντελεστή αυτοσυσχέτισης 1[ης] τάξης και την τιμή της αθροιστικής πιθανότητας P του εκατοστημορίου. Τέλος διενεργείται εφαρμογή της μεθοδολογίας εκτίμησης του ασυμπτωτικού διαστήματος εμπιστοσύνης στη σειρά *πυκνότητα των εκπομπών διοξειδίου του άνθρακα* στην Ελλάδα για τα έτη 1961-2010. Στην εφαρμογή αυτή σχολιάζεται η εγκυρότητα των εκτιμηθέντων διαστημάτων εμπιστοσύνης βάσει των ευρημάτων των πειραμάτων προσομοίωσης αναφορικά με τις τιμές των δύο παραπάνω στατιστικών κριτηρίων.

Λέξεις Κλειδιά: Εκατοστημόρια, περιβαλλοντικά δεδομένα, υποδείγματα χρονικών σειρών, διαστήματα εμπιστοσύνης.
Κωδικοί JEL: C13; C22; C53; Q50; Q54.

[34] Η μελέτη αυτή έχει λάβει χρηματοδότηση από το πρόγραμμα «GHGsMETI", στα πλαίσια του έργου δράσης « ΣΥΝΕΡΓΑΣΙΑ 2011» με κωδικό αριθμό έργου 11SYN_8_118 και υποστηρίζεται από το Ευρωπαϊκό Ταμείο Περιφερειακής Ανάπτυξης και από Ελληνικούς Εθνικούς Πόρους. Το κείμενο εκφράζει τις απόψεις των συγγραφέων.

ΕΥΡΩΠΑΪΚΗ ΕΝΩΣΗ
ΕΥΡΩΠΑΪΚΟ ΤΑΜΕΙΟ
ΠΕΡΙΦΕΡΕΙΑΚΗΣ ΑΝΑΠΤΥΞΗΣ
ΑΝΤΑΓΩΝΙΣΤΙΚΟΤΗΤΑ ΕΠΙΧΕΙΡΗΜΑΤΙΚΟΤΗΤΑ ΕΠΑΝ II
η περιφέρεια στο επίκεντρο της ανάπτυξης
ΕΣΠΑ 2007-2013
πρόγραμμα για την ανάπτυξη
Υπουργείο Παιδείας και Θρησκευμάτων
ΕΥΔΕ-ΕΤΑΚ
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1. ΕΙΣΑΓΩΓΗ

Η κατασκευή διαστημάτων εμπιστοσύνης για εκατοστημόρια αποτελεί πλέον θεματική έρευνας με αυξανόμενο ενδιαφέρον. Ήδη έχει αναγνωρισθεί στη διεθνή βιβλιογραφία η αναγκαιότητα της εκτίμησης εκατοστημορίων σε σειρές μεγεθών που αφορούν διάφορες κοινωνικοοικονομικές μεταβλητές όπως το οικογενειακό εισόδημα, η εξέλιξη του βάρους και τους ύψους των νεογέννητων παιδιών κλπ. Επιπλέον, οι εκτιμήσεις των εκατοστημορίων παίζουν σημαντικό ρόλο σε αποφάσεις που πρέπει να ληφθούν στην άσκηση επιχειρηματικής πολιτικής. Ως παραδείγματα αναφέρουμε τον προσδιορισμό των ασφαλίστρων στο κλάδο ασφαλειών, τη μέτρηση της εγκυρότητας σε θέματα μηχανικής, τον προσδιορισμό της ποσότητας παραγγελίας ή του σημείου αναπαραγγελίας σε υποδείγματα αποθεματικής πολιτικής newsvendor και υποδείγματα συνεχούς επιθεώρησης, και τον προσδιορισμό της συσωρευτικής ικανότητας (assimilative capacity) σε υποδείγματα διαχείρισης του περιβάλλοντος. Ειδικότερα, στον τομέα του περιβάλλοντος, είναι πολύ σημαντικό να αναλυθούν οι επιπτώσεις των διαφόρων περιβαλλοντικών πολιτικών σε ξεχωριστά εκατοστημόρια της οριακής κατανομής της υπό εξέταση περιβαλλοντικής μεταβλητής αποφεύγοντας τα προβλήματα που ανακύπτουν από τη χρήση του μέσου αριθμητικού ως μοναδικής στατιστικής παραμέτρου.

Ένας σημαντικός αριθμός εργασιών έχει ήδη εμφανιστεί στη διεθνή βιβλιογραφία παρουσιάζοντας διαδικασίες στατιστικών ελέγχων και μεθόδους κατασκευής διαστημάτων εμπιστοσύνης για εκατοστημόρια όταν η πληθυσμιακή κατανομή για την υπό μελέτη μεταβλητή είναι άγνωστη. Η πιο σύνηθης προσέγγιση είναι η θεμελίωση απαραμετρικών (distribution-free) διαστημάτων εμπιστοσύνης χρησιμοποιώντας τη σχέση μεταξύ εκατοστημορίων και διάταξης (ordering) και κατάταξης (ranking) των παρατηρήσεων (Gibbons and Chakraborti, 2003. Chakraborti and Li, 2007). Από την άλλη πλευρά, η μέθοδος Bootstrapping αποτελεί σήμερα μια σημαντική εναλλακτική προσέγγιση ανάπτυξης απαραμετρικών διαστημάτων εμπιστοσύνης για εκατοστημόρια εκμεταλευόμενοι τη δύναμη των ηλεκτρονικών υπολογιστών και τις δυνατότητες που δίνουν τα διάφορα εμπορικά υπολογιστικά πακέτα Η/Υ (Efron and Tibshirani, 1993). Επίσης, μια άλλη προσέγγιση εξαγωγής εκτιμητών για εκατοστημόρια βασίζεται στην αριστοποίηση μιας συνάρτησης απωλειών απόλυτων σφαλμάτων (absolute error loss function) χρησιμοποιώντας απαραμετρικές συναρτήσεις πυκνότητας πιθανότητας με το εκατοστημόριο να εκφράζεται ως το άθροισμα μιας παραμέτρου θέσης και το γινόμενο μιας σταθεράς επί μια παράμετρο κλίμακας (Keating 1983; Keating *et al.*, 2010).

Αντίθετα με τα παραπάνω, η εκτίμηση διαστημάτων επιστοσύνης για εκατοστημόρια υπό το πλαίσιο μιας παραμετρικής προσέγγισης έχει λάβει μέχρι τώρα μικρό ερευνητικό ενδιαφέρον. Πιο συγκεκριμένα, ένας μικρός αριθμός εργασιών έχει παρουσιαστεί στη διεθνή βιβλιογραφία υποθέτωντας ότι η κατανομή της υπό εξέταση μεταβλητής είναι η κανονική με άγνωστο μέσο και άγνωστη διακύμανση. Χρησιμοποιώντας το κριτήριο της αποτελεσματικότητας της εγγύτητας κατά Pitman (Pitman-closeness efficiency) οι Dyer *et al.* (1977) έκαναν σύγκριση διαφόρων εκτιμητών για εκατοστημόρια [μεταξύ των εκτιμητών που εξεταστηκαν ήταν οι Maximum Likelihood (ML), Minimum Variance Unbiased Estimator (MVUE), και Best Invariant Estimator (BIE]. Οι Bland and Altman (1999) εξήγαγαν ένα συμμετρικό διάστημα εμπιστοσύνης για εκατοστημόρια χρησιμοποιώντας ιδιότητες των κατανομών δειγματοληψίας του δειγματικού μέσου και της δειγματικής διακύμανσης.

Στην έκταση της γνώσης μας επί του θέματος, οι Chakraborti and Li (2007) ήταν οι πρώτοι που διενήργησαν συγκρίσεις της εγκυρότητας μεταξύ διαφόρων μεθόδων εκτίμησης διαστημάτων εμπιστοσύνης για εκατοστημόρια, όταν η κατανομή της υπό εξέταση μεταβλητής είναι η κανονική με άγνωστο μέσο και άγνωστη διακύμανση. Εκτός των διαστημάτων εμπιστοσύνης τα οποία συνδέονται με τους εκτιμητές ML και MVUE, στην μελέτη αυτή συμπεριλήφθηκαν το διαστήμα εμπιστοσύνης βασιζόμενο στον προσημικό έλεγχο και το διάστημα πρόβλεψης της εκ των υστέρων Μπευνζιανής (Bayesian) ανάλυσης. Ως κριτήρια για τις συγκρίσεις αυτές, οι συγγραφείς χρησιμοποίησαν τις τιμές του πραγματικού επιπέδου εμπιστοσύνης (καλούμενο και ως κάλυψη) και του αναμενόμενου πλάτους του διαστήματος τις οποίες η κάθε μέθοδος επιτύγχανε. Βάσει των κριτηρίων αυτών οι συγγραφείς θεωρούν ως καλή επιλογή τη χρήση των διαστημάτων εμπιστοσύνης πεπερασμένων δειγμάτων που συνδέονται με τους εκτιμητές ML και MVUE, όταν για μεν το πρώτο εκτιμητή χρησιμοποιούνται οι κριτικές τιμές της student-t , ενώ για τον εκτιμητή ML οι κριτικές τιμές της non-central student-t.

Με τη κατανομή της υπό εξέταση μεταβλητής να είναι η κανονική με άγνωστο μέσο και άγνωστη διακύμανση, οι Donner και Zou (2010) παρουσίασαν μια μέθοδο κατασκευής ασυμμετρικών διαστημάτων εμπιστοσύνης χρησιμοποιώντας τη μέθοδο ανάκτησης εκτιμήσεων διακύμανσης (Variance Estimates Recovery). Επίσης στα πλαίσια εκτίμησης της άριστης ποσότητας παραγγελίας σε υποδείγματα αποθεματικής πολιτικής newsvendor ο Kevork (2010) εξήγαγε το ασυμπτωτικό διάστημα εμπιστοσύνης του εκτιμητή ML. Τέλος, θεωρώντας ένα διαχρονικό δείγμα ζήτησης με την οριακή κατανομή να είναι η εκθετική, οι Halkos και Kevork (2013a) εξήγαγαν εκτιμητή ο οποίος διασφαλίζει ότι η πιθανότητα η επόμενη χρονικά παρατήρηση να είναι μικρότερη της άριστης ποσότητας παραγγελίας να ισούται με την αθροιστική πιθανότητα P του εκατοστημορίου.

Η βασική όμως υπόθεση που έγινε σε όλες τις προαναφερθείσες εργασίες ήταν ότι οι παρατηρήσεις στο δείγμα διαμορφώνονται ανεξάρτητα μεταξύ τους. Παρόλα αυτά μπορεί να υπάρξουν περιπτώσεις μεταβλητών για τις οποίες η εξέλιξη των τιμών τους σε έναν συγκεκριμένο χρονικό ορίζοντα να εμφανίζει αυτοσυσχέτιση. Μια τέτοια μεταβλητή παρουσιάζουμε στην εργασία αυτή από το χώρο της Οικονομικής του Περιβάλλοντος που είναι «η *πυκνότητα των εκπομπών διοξειδίου του άνθρακα (CO_2 σε κιλά ανά ισοδύναμο κιλό πετρελαίου) στην Ελλάδα»*[35]. Έχοντας διαθέσιμες τις τιμές της μεταβλητής αυτής για τα έτη 1961-2010, η εφαρμογή κατάλληλων στατιστικών ελέγχων μας οδηγεί στον ισχυρισμό ότι ο στοχαστικός νόμος γέννησης των τιμών της μεταβλητής αυτής είναι ή το στάσιμο AR(1) ή το στάσιμο ARMA(1,1). Με βάση τα ευρήματα αυτά, στην εργασία αυτή πραγματευόμαστε για πρώτη φορά θέματα εκτιμητικής των εκατοστημορίων όταν ο στοχαστικός νόμος γέννησης των τιμών της μεταβλητής είναι η γενική γραμμική στοχαστική ανέλιξη, ειδικές περιπτώσεις της οποίας αποτελούν τα στάσιμα AR(1) και ARMA(1,1).

Πιο συγκεκριμένα, για την εκτίμηση του $100\times P_{th}$ εκατοστημορίου χρησιμοποιούμε τον εκτιμητή μεγίστης πιθανοφάνειας (Dyer *et al.*, 1977) ο οποίος αποτελεί γραμμική συνάρτηση του δειγματικού μέσου και του εκτιμητή μεγίστης πιθανοφάνειας της

[35] Πηγή των δεδομένων η World Bank.

δειγματικής διακύμανσης. Για τον εκτιμητή μεγίστης πιθανοφάνειας (ML) του $100 \times P_{th}$ εκατοστημορίου εξάγουμε την ασυμπτωτική του κατανομή από την οποία λαμβάνουμε το αντίστοιχο ασυμπτωτικό διάστημα εμπιστοσύνης. Στη συνέχεια, για την εξέταση της εγκυρότητας της εκτίμησης του διαστήματος αυτού σε πεπερασμένα δείγματα, χρησιμοποιούμε στάσιμες σειρές από το AR(1) και ARMA(1,1) τις οποίες παράγουμε μέσω προσομοιώσεων Monte-Carlo.

Χρησιμοποιώντας τις δημιουργημένες αυτές σειρές, η μελέτη της εγκυρότητας διενεργείται υπολογίζοντας για διαφορετικούς συνδυασμούς μεγέθους δείγματος και αθροιστικής πιθανότητας του εκατοστημορίου τις τιμές δυο στατιστικών κριτηρίων: (α) του πραγματικού επιπέδου εμπιστοσύνης, και (β) του αναμενόμενου ημι-πλάτους του διαστήματος διαρούμενου με το πραγματικό μέγεθος του εκατοστημορίου. Από τις τιμές των δύο αυτών στατιστικών κριτηρίων διαπιστώνουμε ότι η εγκυρότητα του εκτιμηθέντος ασυμπτωτικού διαστήματος σε πεπερασμένα δείγματα εξαρτάται από το μέγεθος του δείγματος, από τη μορφή του στοχαστικού υποδείγματος, AR(1) ή ARMA(1,1), που γεννά τις τιμές της μεταβλητής όταν τα δύο αυτά υποδείγματα έχουν τον ίδιο συντελεστή αυτιοσυσχέτισης 1ης τάξης, και από την αθροιστική πιθανότητα του εκατοστημορίου.

Η εργασία αυτή κλείνει με εφαρμογή της μεθοδολογίας εκτίμησης των ασυμπτωτικών διαστημάτων εμπιστοσύνης για εκατοστημόρια στην διαθέσιμη σειρά από το χώρο της Οικονομικής του Περιβάλλοντος. Ειδικότερα, εκτιμώντας τα διαστήματα αυτά για εκατοστημόρια που αναφέρονται στην πυκνότητα των εκπομπών διοξειδίου του άνθρακα στην Ελλάδα την περίοδο 1961-2010 για διαφορετικές τιμές της αθροιστικής πιθανότητας P, σχολιάζουμε την εγκυρότητα αυτών βάσει των ευρημάτων που αποκτήθηκαν από τη διεξαγωγή των προσομοιώσεων Monte-Carlo αναφορικά με τις υπολογισθείσες τιμές των δυο παραπάνω στατιστικών κριτηρίων αξιολόγησης.

Με βάση τα παραπάνω, το υπόλοιπο της εργασίας αυτής δομείται ως εξής. Στο επόμενο τμήμα εξάγουμε την ασυμπτωτική κατανομή του εκτιμήτη ML του εκατοστημορίου και δίνουμε τη γενική μορφή του αντίστοιχου ασυμπτωτικού διαστήματος εμπιστοσύνης. Εξειδικεύσεις της γενικής αυτής μορφής εξάγονται για τα στάσιμα υποδείγματα AR(1) και ARMA(1,1). Στο τρίτο τμήμα αιτιολογούμε μέσω εφαρμογής κατάλληλων στατιστικών ελέγχων ότι η σειρά που αναφέρεται στην πυκνότητα των εκπομπών Διοξειδίου του Άνθρακα στην Ελλάδα την περίοδο 1961-2010 έχει ως στοχαστικό νόμο παραγωγής των τιμών της ή το στάσιμο AR(1) ή το στάσιμο ARMA(1,1). Έχοντας διαθέσιμες τις εξειδικευμένες μορφές των ασυμπτωτικών διαστημάτων εμπιστοσύνης εκατοστημορίων για τα δύο αυτά στάσιμα υποδείγματα, στο ίδιο Τμήμα εκτιμούμε τα ασυμπτωτικά διαστήματα για διαφορετικές τιμές της αθροιστικής πιθανότητας του εκατοστημορίου. Ο έλεγχος της εγκυρότητας των εκτιμηθέντων αυτών διαστημάτων διενεργείται μέσω προσομοιώσεων Monte-Carlo στο τέταρτο Τμήμα. Τέλος στο πέμπτο και τελευταίο Τμήμα της εργασίας συνοψίζουμε τα πιο σημαντικά ευρήματα της μελέτης αυτής.

2. ΑΣΥΜΠΤΩΤΙΚΑ ΔΙΑΣΤΗΜΑΤΑ

Έστω ότι η διαχρονική εξέλιξη της υπό μελέτη μεταβλητής περιγράφεται από τη γενική γραμμική ανέλιξη,

$$X_t = \mu + \sum_{s=0}^{\infty} \psi_s \varepsilon_{t-s}, \qquad (1)$$

όπου $\sum_{s=0}^{\infty} |\psi_j| < \infty$, και $\{\varepsilon_t\}$ ανεξάρτητες τυχαίες μεταβλητές κατανεμόμενες ως $N(0,\sigma^2)$. Με την οριακή κατανομή της $\{X_t\}$ να είναι η $N(0,\gamma_o)$, το $100 \times P_{th}$ εκατοστημόριό της θα δίνεται από τη σχέση $K_P = \mu + Z_P \sqrt{\gamma_o}$, όπου Z_P είναι η τιμή της αντίστροφης συνάρτησης αθροιστικής κατανομής της $Z \sim N(0,1)$ υπολογιζόμενη στην αθροιστική πιθανότητα P. Για την εκτίμηση του εκατοστημορίου K_P θα χρησιμοποιηθεί ο «μεροληπτικός» εκτιμητής μεγίστης πιθανοφάνειας $\hat{K}_P = \overline{X} + Z_P \sqrt{\hat{\gamma}_o}$, όπου $\overline{X} = \sum_{t=1}^{n} X_t \big/ n$ και $\hat{\gamma}_o = \sum_{t=1}^{n} (X_t - \overline{X})^2 \big/ n$. Τα αποτελέσματα των παρακάτω δυο λημμάτων είναι απαραίτητα στην ανάλυση που θα ακολουθήσει για την εξαγωγή του ασυμπτωτικού διαστήματος εμπιστοσύνης για την πραγματική τιμή K_P.

Λήμμα 1: Εάν $X_t = \mu + \sum_{s=0}^{\infty} \psi_s \varepsilon_{t-s}$, όπου $\sum_{s=0}^{\infty} |\psi_j| < \infty$, με $\{\varepsilon_t\}$ να είναι ανεξάρτητες τυχαίες μεταβλητές κατανεμόμενες ως $N(0,\sigma^2)$, τότε:

(α) $\sqrt{n}(\overline{X} - \mu)$ ασυμπτωτικά ακολουθεί την κανονική κατανομή με μέσο 0 και διακύμανση $\gamma_o \sum_{s=-\infty}^{+\infty} \rho_s$, και

(β) $\sqrt{n}(\hat{\gamma}_o - \gamma_o)$ ασυμπτωτικά ακολουθεί την κανονική κατανομή με μέσο 0 και διακυμάνση $2\gamma_o^2 \sum_{s=-\infty}^{+\infty} \rho_s^2$,

όπου ρ_s είναι ο συντελεστής αυτοσυσχέτισης s^{th} τάξης.

Απόδειξη: Βλέπε στο Παράρτημα.

Λήμμα 2: Εάν $X_t = \mu + \sum_{s=0}^{\infty} \psi_s \varepsilon_{t-s}$, όπου $\sum_{s=0}^{\infty} |\psi_j| < \infty$, με $\{\varepsilon_t\}$ να είναι ανεξάρτητες τυχαίες μεταβλητές κατανεμόμενες ως $N(0,\sigma^2)$, τότε για οποιοδήποτε μέγεθος δείγματος η συνδιακύμανση των $\overline{X}_n$ and $\hat{\gamma}_o$ είναι μηδέν.

Απόδειξη: Βλέπε απόδειξη Πρότασης 2 στο Παράρτημα των Halkos and Kevok (2013b).

Βάσει των αποτελεσμάτων των δυο παραπάνω λημμάτων, το διάνυσμα $\sqrt{n}\left[\overline{X}-\mu \quad \hat{\gamma}_o-\hat{\gamma}_o\right]'$ ασυμπτωτικά ακολουθεί τη διμεταβλητή κατανομή με μέσο **0** και μήτρα διακύμανσης-συνδιακύμανσης $\boldsymbol{\Sigma}=\begin{bmatrix}\gamma_o\sum_{s=-\infty}^{+\infty}\rho_s & 0\\ 0 & 2\gamma_o^2\sum_{s=-\infty}^{+\infty}\rho_s^2\end{bmatrix}$. Δοθέντος του P, ισχύει επίσης ότι $\operatorname{plim}\hat{K}_P=\operatorname{plim}\overline{X}_n+Z_P(\operatorname{plim}\hat{\gamma}_o)^{0.5}=\mu+Z_P\sqrt{\gamma_o}=K_P$. Επομένως η εφαρμογή της μεθόδου Δέλτα (Knight, 2000, σελ. 149) οδηγεί στην ασυμπτωτική κατανομή του στατιστικού $\sqrt{n}\left(\hat{K}_P-K_P\right)$, η οποία είναι η κανονική με μέσο μηδέν και διακύμανση $\mathbf{L}'\cdot\boldsymbol{\Sigma}\cdot\mathbf{L}$ όπου

$$L'=\left[\left.\frac{\partial\hat{K}_P}{\partial\overline{X}_n}\right|_{\substack{\overline{X}_n=\mu\\ \hat{\gamma}_o=\gamma_o}} \quad \left.\frac{\partial\hat{K}_P}{\partial\hat{\gamma}_o}\right|_{\substack{\overline{X}_n=\mu\\ \hat{\gamma}_o=\gamma_o}}\right]=\left[1 \quad \frac{Z_P}{2\sqrt{\gamma_o}}\right]$$

και $\mathbf{L}'\cdot\boldsymbol{\Sigma}\cdot\mathbf{L}=\gamma_o\left\{\sum_{s=-\infty}^{+\infty}\rho_s+\frac{Z_P^2}{2}\sum_{k=-\infty}^{+\infty}\rho_s^2\right\}$. Επομένως το ασυμπτωτικό $(1-\alpha)100\%$ διάστημα εμπιστοσύνης για το $100\times P_{th}$ εκατοστημόριο δίνεται από τον τύπο

$$\hat{K}_P\pm z_{\alpha/2}\sqrt{\frac{\gamma_o}{n}\left(\sum_{s=-\infty}^{+\infty}\rho_s+\frac{Z_P^2}{2}\sum_{k=-\infty}^{+\infty}\rho_s^2\right)}\,. \tag{2}$$

Το διάστημα εμπιστοσύνης της (2) μπορεί να εξειδικευθεί για εναλλακτικά στάσιμα ARMA υποδείγματα. Παρακάτω δίνουμε δύο χαρακτηριστικά παραδείγματα.

Παράδειγμα 1:Το στάσιμο αυτοπαλίνδρο σχήμα 1ου Βαθμού, AR(1).

Το υπόδειγμα αυτό έχει τη γενική μορφή $X_t=\mu+\phi(X_{t-1}-\mu)+\varepsilon_t$, με $|\phi|<1$, $\gamma_o=\sigma^2/(1-\phi^2)$, και $\rho_k=\phi^k$ (k=0, 1, 2,…). Θεωρώντας ότι η ανέλιξη έχει ξεκινήσει στο μακρυνό παρελθόν, και αντικαθιστώντας διαδοχικά για Y_{t-1}, Y_{t-2}, Y_{t-3}, …, το AR(1) λαμβάνει τη μορφή της γενικής γραμμικής ανέλιξης της σχέσης (1) με $\psi_j=\phi^j$. Επιπλέον ισχύει ότι

$$\sum_{s=-\infty}^{\infty}\rho_s=1+\frac{2\phi}{1-\phi}=\frac{1+\phi}{1-\phi} \qquad \text{και} \qquad \sum_{s=-\infty}^{\infty}\rho_s^2=1+\frac{2\phi^2}{1-\phi^2}=\frac{1+\phi^2}{1-\phi^2}.$$

Επομένως το διάστημα εμπιστοσύνης στην (2) για το AR(1) εξειδικεύεται ως

$$\hat{K}_P\pm z_{\alpha/2}\sqrt{\frac{\gamma_o}{n}\left(\frac{1+\rho_1}{1-\rho_1}+\frac{z_R^2}{2}\frac{1+\rho_1^2}{1-\rho_1^2}\right)}\quad, \tag{3}$$

καθώς ισχύει $\rho_1=\phi$.

Παράδειγμα 2: Το στάσιμο και αντιστρέψιμο σχήμα ARMA(1,1).
Το υπόδειγμα αυτό έχει τη γενική μορφή $X_t = \mu + \phi(X_{t-1} - \mu) + \varepsilon_t + \theta\varepsilon_{t-1}$, με $|\phi| < 1$, $|\theta| < 1$, $\gamma_o = \dfrac{1+\theta^2+2\phi\theta}{1-\phi^2}\sigma^2$, $\rho_1 = \dfrac{(1+\phi\theta)(\phi+\theta)}{1+\theta^2+2\phi\theta}$, και $\rho_k = \phi^{k-1}\rho_1$ για $k \geq 2$. Θεωρώντας ότι η ανέλιξη έχει ξεκινήσει στο μακρυνό παρελθόν, ο Harvey (1993, σελ. 26) δείχνει ότι το ARMA(1,1) λαμβάνει τη μορφή της γενικής γραμμικής ανέλιξης της σχέσης (1) με $\psi_o = 1$, $\psi_1 = \phi + \theta$, και $\psi_k = \phi\psi_{k-1}$ για $k \geq 2$. Επιπλέον ισχύουν οι παρακάτω σχέσεις

$$\sum_{s=-\infty}^{\infty}\rho_s = 1 + 2\rho_1/(1-\phi) \qquad \text{και} \qquad \sum_{s=-\infty}^{\infty}\rho_s^2 = 1 + 2\rho_1^2/\left(1-\phi^2\right).$$

Επομένως το διάστημα εμπιστοσύνης στην (1) για το ARMA(1,1) εξειδικεύεται ως

$$\hat{K}_P \pm z_{\alpha/2}\sqrt{\frac{\gamma_o}{n}\left(1 + \frac{2\rho_1^2}{\rho_1-\rho_2} + \frac{z_R^2}{2}\left(1 + \frac{2\rho_1^4}{\rho_1^2-\rho_2^2}\right)\right)}, \tag{4}$$

μετά την αντικατάσταση του ϕ από το λόγο ρ_2/ρ_1.

3. ΕΦΑΡΜΟΓΗ ΣΕ ΠΕΡΙΒΑΛΛΟΝΤΙΚΑ ΔΕΔΟΜΕΝΑ

Για τα έτη 1961-2010, το Διάγραμμα 1 παρουσιάζει τη διαχρονική εξέλιξη της υπό μελέτη περιβαλλοντικής μεταβλητής, X_t, που είναι η πυκνότητα των εκπομπών Διοξειδίου του Άνθρακα (CO_2, σε κιλά ανά ισοδύναμο κιλό πετρελαίου) στην Ελλάδα. Για τον έλεγχο της στασιμότητας της σειράς, εφαρμόστηκαν έλεγχοι ADF, τα αποτελέσματα των οποίων παρουσιάζονται στον Πίνακα 1. Έχοντας ως ανεξάρτητη μεταβλητή την ΔX_t και ως ερμηνευτικές, εκτός του σταθερού όρου, τη μεταβλητή X_{t-1}, τη μεταβλητή χρονικής τάσης, t, και τις μεταβλητές χρονικών υστερήσεων διαφορών ΔX_{t-j}, εναλλακτικές εξισώσεις εκτιμήθηκαν για $j = 1,...,10$. Η χρήση του κριτηρίου Schwarz έδειξε ότι στην εκτιμηθείσα εξίωση δεν πρέπει να χρησιμοποιηθούν μεταβλητές χρονικών υστερήσεων διαφορών. Χωρίς τη χρήση των μεταβλητών αυτών, η εκτιμηθείσα εξίσωση παρουσιάζεται στον Πίνακα 1 ως εκτιμηθέν Υπόδειγμα 1. Παρατηρούμε όμως, ότι στο υπόδειγμα αυτό ο συντελεστής της μεταβλητής χρονικής τάσης είναι μη στατιστικά σημαντικός σε επίπεδο 5%. Χωρίς τη μεταβλητή χρονικής τάσης, η νέα εκτιμηθείσα εξίσωση παρουσιάζεται επίσης στο Πίνακα 1 ως εκτιμηθέν υπόδειγμα 2. Παρόλα αυτά, χρησιμοποιώντας είτε το εκτιμηθέν υπόδειγμα 1 είτε το εκτιμηθέν υπόδειγμα 2, παρατηρούμε ότι σε επίπεδο στατιστικής σημαντικότητας 5%, η υπόθεση της μοναδιαίας ρίζας απορρίπτεται, γεγονός το οποίο μας οδηγεί να ισχυριστούμε ότι η υπό μελέτη σειρά είναι στάσιμη.

Στα Διαγράμματα 2 και 3 παρουσιάζουμε αντίστοιχα τη συνάρτηση δειγματικής αυτοσυσχέτισης και τη συνάρτηση δειγματικής μερικής αυτοσυσχέτισης. Οι μορφές των δειγματικών αυτών συναρτήσεων είναι ενδεικτικές είτε για υπόδειγμα AR(1) είτε για ARMA(1,1). Με τη χρήση της μεθόδου OLS παρουσιάζουμε παρακάτω τα εκτιμημένα δυο αυτά υποδείγματα με τα p-values να δίνονται στις παρενθέσεις:

Εκτιμημένο AR(1): $\hat{Y}_t = 1.318230 + 0.614890\, Y_{t-1} + \hat{\varepsilon}_t$

$$\underset{(0.0011)}{1.318230} \quad \underset{(0.0000)}{0.614890}$$

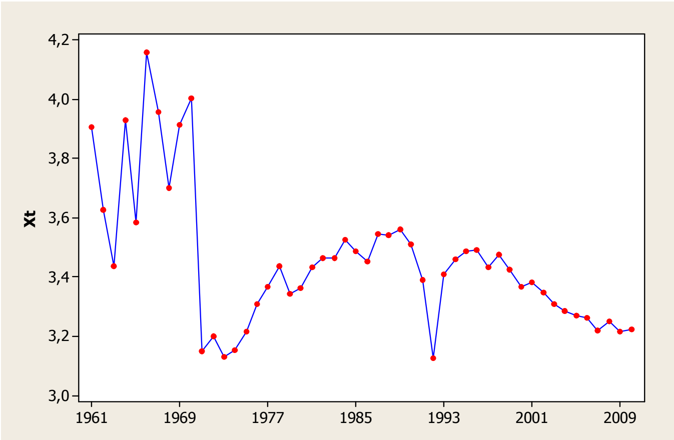
$\hat{\sigma}_{\varepsilon} = 0.180552$,

Εκτιμημένο ARMA(1): $\hat{Y}_t = 3.402104 + 0.782531\, Y_{t-1} - 0.285921\, \hat{\varepsilon}_{t-1} + \hat{\varepsilon}_t$

$$\underset{(0.0000)}{3.402104} \quad \underset{(0.0000)}{0.782531} \quad \underset{(0.1706)}{0.285921}$$

$\hat{\sigma}_{\varepsilon} = 0.179286$.

Διάγραμμα 1: Διαχρονική εξέλιξη της πυκνότητας εκπομπών διοξειδίου του Άνθρακα (CO_2) (σε κιλά ανά ισοδύναμο κιλό πετρελαίου) στην Ελλάδα το διάστημα 1961-2010.



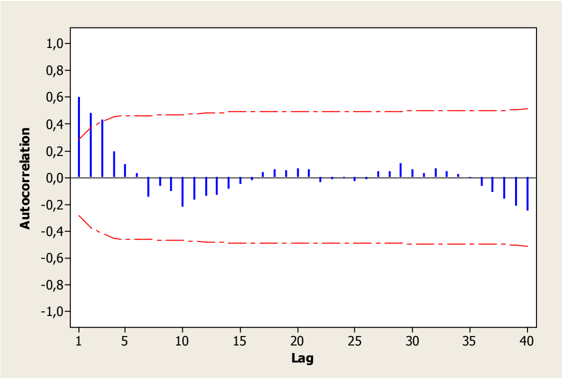
Πίνακας 1: Αποτελέσματα στατιστικών ελέγχων Augmented Dickey Fuller (ADF)

	Constant term	Time-Trend	X_{t-1}	ADF Test Value	ADF p-value
Εκτιμηθέν Υπόδειγμα 1					
Coefficient:	1.806002	-0.003701	-0.499376	-3.996764	0.0152
p-value:	0.0003	0.0815	0.0002		
Εκτιμηθέν Υπόδειγμα 2					
Coefficient:	1.318230		-0.385110	-3.511855	0.0117
p-value:	0.0010		0.0011		

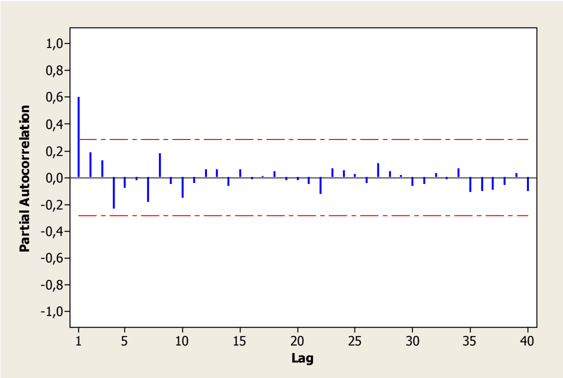
Για την περαιτέρω αξιολόγηση των εκτιμηθέντων AR(1) και ARMA(1,1), στα διαγράμματα 4 και 5 παρουσιάζουμε τις συναρτήσεις αυτοσυσχέτισης των καταλοίπων για τα δύο υποδείγματα αντίστοιχα. Επιπλέον στον Πίνακα 2 δίνουμε τα αποτελέσματα και τις τιμές P (p-values) των διαγνωστικών ελέγχων Jarque-Bera για κανονικότητα και ARCH-LM για αυτοπαλίνδρομη υπό συνθήκη ετεροσκεδαστικότητα. Καταρχάς παρατηρούμε στα δύο διαγράμματα ότι κανένας δειγματικός συντελεστής αυτοσυσχέτισης των καταλοίπων δεν βρίσκεται εκτός των δυο γραμμών οριοθέτησης. Άρα τα σφάλματα και στα δυο υποδείγματα εμφανίζονται ως ασυσχέτιστα. Επιπλέον τα p-values των στατιστικών F και nR^2 δίνουν ισχυρές ενδείξεις στο να αποφανθούμε ότι στα σφάλματα των δυο υποδειγμάτων δεν υπάρχει αποτέλεσμα ARCH. Το μόνο ίσως πρόβλημα που ανακύπτει στα κατάλοιπα των εκτιμηθέντων δύο υποδειγμάτων αφορά τις τιμές P του ελέγχου Jarque-

Bera, τα οποία υποδεικνύουν ότι τα σφάλματα δεν ακολουθούν τη κανονική κατανομή. Παρόλα αυτά, εμείς θα παραβλέψουμε το πρόβλημα αυτό και θα συνεχίσουμε στην εκτίμηση των εκατοστημορίων και των αντίστοιχων ασυμπτωτικών διαστημάτων εμπιστοσύνης για την υπό εξέταση μεταβλητή όταν ο στοχαστικός νόμος που παράγει τις τιμές αυτής είναι είτε το AR(1) είτε το ARMA(1,1).

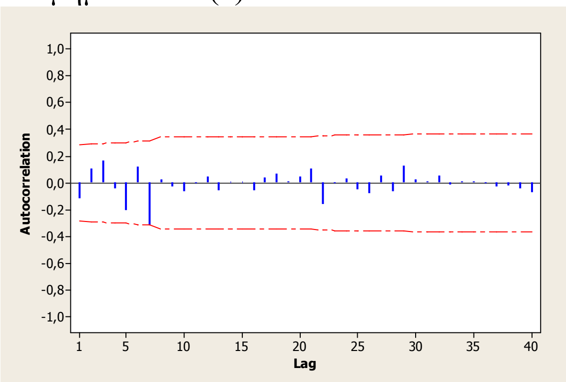
Διάγραμμα 2: Συνάρτηση δειγματικής αυτοσυσχέτισης της μεταβλητής X_t



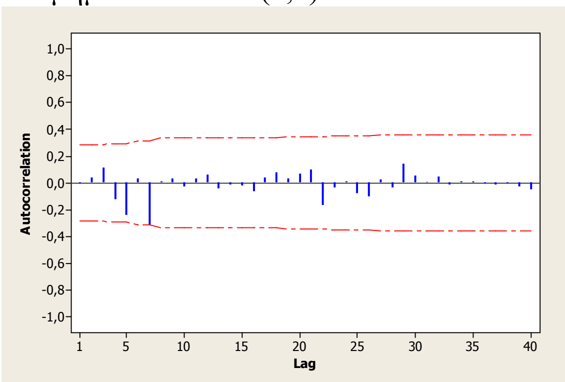
Διάγραμμα 3: Συνάρτηση δειγματικής μερικής αυτοσυσχέτισης της μεταβλητής X_t



Διάγραμμα 4: Συνάρτηση δειγματικής αυτοσυσχέτισης των καταλοίπων του εκτιμημένου AR(1)



Διάγραμμα 5: Συνάρτηση δειγματικής αυτοσυσχέτισης των καταλοίπων του εκτιμημένου ARMA(1,1)



Για διαφορετικές τιμές της αθροιστικής πιθανότητας P του εκατοστημορίου, στον Πίνακα 3 δίνουμε για τα δύο υποδείγματα τις εκτιμήσεις των εκατοστημορίων και τα κάτω και πάνω όρια των 95% ασυμπτωτικών διαστημάτων εμπιστοσύνης, οι μορφές των οποίων δίνονται στις σχέσεις (3) και (4). Για την εκτίμηση του δειγματοληπτικού σφάλματος στις δύο αυτές μορφές των ασυμπτωτικών διαστημάτων εμπιστοσύνης, το γ_o αντικαταστάθηκε από την εκτίμησή του $\hat{\gamma}_o$, ενώ οι συντελεστές αυτοσυσχέτισης $\hat{\rho}_1$ και $\hat{\rho}_2$ εκτιμήθηκαν βάσει του τύπου (Harvey, 1993, σελ. 11)

$$\hat{\rho}_s = \frac{\sum_{t=s+1}^{n}\left(X_t - \overline{X}\right)\left(X_{t-s} - \overline{X}\right)}{\sum_{t=1}^{n}\left(X_t - \overline{X}\right)^2}, \ s=1,2.$$

Πίνακας 2: Αποτελέσματα διαγνωστικών ελέγχων για τα κατάλοιπα των εκτιμηθέντων AR(1) και ARMA(1,1)

Test	**Jarque-Bera**	**$ARCH_{LM}(1)$**	
		F-statistic	n*R2
AR(1)			
Test statistic	65.93892	0.083217	0.086678
p-value	(0.0000)	(0.7743)	(0.7684)
ARMA(1,1)			
Test statistic	49.63137	0.415192	0.429369
p-value	(0.0000)	(0.5225)	(0.5123)

Από την εξέταση των στοιχείων του Πίνακα 3 διαπιστώνουμε τα εξής: (α) Όπως αναμενόταν η αύξηση της αθροιστικής πιθανότητας P οδηγεί σε μεγαλύτερες εκτιμήσεις για το εκατοστημόριο K_P, και (β) για τα δύο υποδείγματα, η σχετική ακρίβεια των διαστημάτων εμπιστοσύνης μειώνεται (δηλαδή το πλάτος του διαστήματος εμπιστοσύνης ως ποσοστό του K_P αυξάνεται) με την αύξηση του P.

Πίνακας 3: Εκτιμήσεις για τα εκατοστημόρια της πυκνότητας των εκπομπών διοξειδίου του άνθρακα (CO_2, σε κιλά ανά ισοδύναμο κιλό πετρελαίου) στην Ελλάδα. [P η αθροιστική πιθανότητα του εκατοστημορίου, $\hat{K}_P$ η εκτίμηση του εκατοστημορίου, LL και UL τα πάνω και κάτω όρια του 95% διαστήματος εμπιστοσύνης για το K_P, και REHL το ήμισυ της διαφοράς (UL–LL) διαιρούμενης με $\hat{K}_P$].

P	$\hat{K}_P$	AR(1)			ARMA(1,1)		
		LL	UL	REHL	LL	UL	REHL
0.2	3.256484	3.114648	3.398319	0.0436	3.069941	3.443027	0.0573
0.3	3.331078	3.196283	3.465873	0.0405	3.152175	3.509981	0.0537
0.4	3.394817	3.263583	3.526050	0.0387	3.219751	3.569882	0.0516
0.45	3.424842	3.294440	3.555244	0.0381	3.250669	3.599015	0.0509
0.55	3.483941	3.353539	3.614343	0.0374	3.309768	3.658114	0.0500
0.5	3.454391	3.324262	3.584521	0.0377	3.280511	3.628272	0.0503
0.6	3.513966	3.382733	3.645200	0.0373	3.338900	3.689032	0.0498
0.8	3.652299	3.510464	3.794135	0.0388	3.465756	3.838842	0.0511
0.9	3.755749	3.599815	3.911683	0.0415	3.553718	3.957780	0.0538
0.95	3.841180	3.670611	4.011749	0.0444	3.622853	4.059507	0.0568
0.99	4.001434	3.798314	4.204554	0.0508	3.746279	4.256589	0.0638
0.999	4.181062	3.936410	4.425713	0.0585	3.878137	4.483987	0.0725

Κλείνοντας το τμήμα αυτό, είναι αξιοσημείωτο να θέσουμε δυο ζητήματα. Το πρώτο αφορά τη σύγκριση των διαστημάτων εμπιστοσύνης μεταξύ του AR(1) και του ARMA(1,1). Μια τέτοια σύγκριση στο δείγμα των 50 ετών δεν είναι εφικτή για δυο λόγους. Ο πρώτος είναι ότι ο συντελεστής του $\hat{\varepsilon}_{t-1}$ στο εκτιμηθέν ARMA(1,1) δεν είναι όπως φαίνεται στατιστικά σημαντικός βάσει μιας τιμής P την οποία δεν γνωρίζουμε σε ποια τιμή θα διαμορφωνόταν (μικρή ή μεγάλη) εάν είχαμε ένα δείγμα αρκούντως μεγάλο. Ο δεύτερος λόγος είναι ο διαφορετικός εκτιμημένος συντελεστής αυτοσυσχέτισης πρώτης τάξης για τα δύο υποδείγματα. Πιο συγκεκριμένα, χρησιμοποιώντας τις εκτιμηθείσες τιμές των ϕ και θ στον αντίστοιχο τύπο του θεωρητικού συντελεστή αυτοσυσχέτισης πρώτης τάξης του κάθε υποδείγματος θα παίρναμε για το AR(1) $\hat{\rho}_1 = 0.614890$ και για το ARMA(1,1) $\hat{\rho}_1 = 0.607784$.

Το δεύτερο ζήτημα αφορά την ερμηνεία του κάθε διαστήματος εμπιστοσύνης για το διαφορετικό εκατοστημόριο K_P. Η αθροιστική πιθανότητα P του εκατοστημορίου αφορά για τη συγκεκριμένη σειρά ποσοστό ετών. Επομένως για P=0.80, μπορούμε να ισχυριστούμε ότι εάν οι εξωτερικές συνθήκες διαμόρφωσης των τιμών της σειράς παραμείνουν οι ίδιες, στο 80% των ετών, με πιθανότητα 95% η πυκνότητα των εκπομπών διοξειδίου του άνθρακα θα κυμανθεί μεταξύ 3.510464 και 3.794135 σε κιλά ανά ισοδύναμο κιλό πετρελαίου στην περίπτωση του AR(1) και μεταξύ 3.465756 και 3.838842 κιλών για το ARMA(1,1).

4. ΔΙΕΡΕΥΝΗΣΗ ΤΗΣ ΕΓΚΥΡΟΤΗΤΑΣ ΤΩΝ ΑΣΥΜΠΤΩΤΙΚΏΝ ΔΙΑΣΤΗΜΑΤΩΝ ΕΜΠΙΣΤΟΣΥΝΗΣ

Στο τμήμα αυτό ελέγχουμε την εγκυρότητα των κατασκευασθέντων διαστημάτων εμπιστοσύνης για τις πραγματικές τιμές των εκατοστημορίων της οριακής κατανομής των εκπομπών διοξειδίου του άνθρακα, όταν ο στοχαστικός νόμος που παράγει τις τιμές της συγκεκριμένης μεταβλητής περιγράφεται είτε από το στάσιμο AR(1) είτε από το στάσιμο ARMA(1,1). Η διερεύνηση αυτή διενεργείται υπολογίζοντας τα παρακάτω δυο στατιστικά κριτήρια σε 20000 σειρές στάσιμων AR(1) και σε 20000 σειρές στάσιμων ARMA(1,1) οι οποίες παρήχθησαν μέσω προσωμοιώσεων Monte-Carlo:
(α) **Κάλυψη** (Coverage) που δείχνει το πραγματικό επίπεδο εμπιστοσύνης που επιτυγχάνει σε πεπερασμένα δείγματα το εκτιμημένο ασυμπτωτικό διάστημα εμπιστοσύνης, και
(β) **Σχετικό Αναμενόμενο Ημι-πλάτος** του διαστήματος (Relative Expected Half-Length, REHL).
Ας σημειωθεί επίσης ότι η γεννήτρια τυχαίων αριθμών που χρησιμοποιήθηκε καθώς και η μέθοδος παραγωγής τυχαίων τιμών από τη τυποποιημένη κανονική κατανομή περιγράφονται στον Kevork (2010).

Η επιλογή των παραμέτρων για τα υποδείγματα AR(1) και ARMA(1,1) έγινε βάσει δυο αρχών: (α) Η οριακή κατανομή της υπό μελέτη μεταβλητής να έχει τον ίδιο στάσιμο μέσο $\mu = 100$ και την ίδια διακύμανση $\gamma_o = 400$, και (β) ο συντελεστής αυτοσυσχέτισης $1^{ης}$ τάξης να έχει την ίδια τιμή και στα δυο υποδείγματα. Με βάση τις δυο αυτές αρχές, οι τιμές των παραμέτρων για τα δυο υποδείγμα είναι οι εξής:

$\rho_1 = 0.56$	
AR(1):	$\phi = 0.56$, $\sigma_\varepsilon^2 = 274.56$
ARMA(1,1):	$\phi = 0.3$, $\theta = 0.4$, $\sigma_\varepsilon^2 = 260$

Για την επίτευξη στασιμότητας σε κάθε μια από τις 20000 προσομοιωμένες σειρές από το κάθε υπόδειγμα, η τιμή X_0 παρήχθη από τη στάσιμη οριακή κατανομή $N(100,400)$, και επιπλέον για το ARMA(1,1) η αρχική τιμή ε_0 παρήχθη από την κατανομή των σφαλμάτων $N(0,260)$. Στη συνέχεια, η διερεύνηση της εγκυρότητας των εκτιμηθέντων ασυμπτωτικών διαστημάτων εμπιστοσύνης, όπως αυτά δίνονται στις σχέσεις (3) και (4), διενεργήθηκε για διαφορετικούς συνδυασμούς μεγέθους δείγματος και διαφορετικές τιμές της αθροιστικής πιθανότητας, P, του εκατοστημορίου. Ειδικότερα, για κάθε μια από τις 20000 παραχθείσες σειρές από το κάθε υπόδειγμα, και για κάθε ένα συνδυασμό μεγέθους δείγματος, n, και αθροιστικής πιθανότητας, P, εκτιμήθηκαν το εκατοστημόριο, το δειγματοληπτικό σφάλμα του διαστήματος εμπιστοσύνης, και τα όρια του διαστήματος εμπιστοσύνης.

Με βάση τις εκτιμήσεις αυτές, για κάθε ένα συνδυασμό n και P, υπολογίσθηκαν η κάλυψη ως το ποσοστό των 20000 διαστημάτων εμπιστοσύνης τα οποία περιείχαν την πραγματική τιμή του εκατοστημορίου, και το REHL ως ο μέσος αριθμητικός του ημι-πλάτους των 20000 διαστημάτων εμπιστοσύνης διαιρούμενος με την πραγματική τιμή του εκατοστημορίου. Η διαίρεση του αναμενόμενου Ημι-πλάτους του διαστήματος με την πραγματική τιμή του εκατοστημορίου κρίνεται αναγκαία για τη διασφάλιση της συγκρισιμότητας της ακρίβειας διαστημάτων εμπιστοσύνης που κατασκευάζονται για διαφορετικές τιμές του P. Και αυτό γιατί με την αύξηση του P, αυξάνεται και η τιμή του εκατοστημορίου.

Ένα πρόβλημα που ανέκυψε σε ορισμένες σειρές από το ARMA(1,1) ήταν ότι σε χαμηλά μεγέθη δείγματος η εκτίμηση της διακύμανσης του $\hat{K}_P$ ήταν αρνητική. Στο Πίνακα 4 δίνουμε τον αριθμό των σειρών αυτών για διαφορετικές τιμές του P. Παρατηρούμε ότι ένας σημαντικός αριθμός τέτοιων σειρών εμφανίζεται για πολύ χαμηλά μεγέθη δείγματος της τάξεως των 5 και 10 παρατηρήσεων, ενώ ο αριθμός αυτός αρχίζει να γίνεται αμελητέος έως και μηδενικός για μεγέθη δείγματος άνω των 30 παρατηρήσεων. Επιπλέον, για τα πολύ χαμηλά μεγέθη δείγματος, ο αριθμός των σειρών αυτών αυξάνει όσο μετακινούμαστε στη τιμή P=0.50 για την οποία λαμβάνουμε το μέσο αριθμητικό.

Στη συνέχεια για τα δύο υποδείγματα AR(1) και ARMA(1,1), και για ονομαστικό επίπεδο εμπιστοσύνης 95%, στον Πίνακα 5 δίνουμε τις τιμές της κάλυψης ενώ στον Πίνακα 6 τις τιμές του REHL. Για το ARMA(1,1), σε χαμηλά μεγέθη δείγματος, οι τιμές των δύο αυτών στατιστικών κριτηρίων υπολογίσθηκαν ως μέσοι όροι των αριθμών των σειρών για τις οποίες η εκτιμηθείσα διακύμανση του $\hat{K}_P$ ήταν θετική. Από τα στοιχεία του Πίνακα 5 διαπιστώνουμε ότι σε χαμηλά μεγέθη δείγματος η κάλυψη είναι σημαντικά μικρότερη του 95%, ενώ με την αύξηση του μεγέθους του δείγματος η ταχύτητα σύγκλισης της κάλυψης στο ονομαστικό επίπεδο εμπιστοσύνης είναι σχετικά πιο γρήγορη στο ARMA(1,1). Δεχόμενοι επίσης ότι μια κάλυψη της τάξεως άνω του 90% αποτελεί μια αποδεκτή προσέγγιση του ονομαστικού επιπέδου εμπιστοσύνης, ένα δείγμα 50 παρατηρήσεων και πάνω διασφαλίζει την εγκυρότητα του ασυμπτωτικού διαστήματος εμπιστοσύνης. Αντίθετα εάν γίνουμε άκρως αυστηροί στην προσέγγιση αυτή και επιθυμούμε καλύψεις πχ. άνω του 94%, τότε το απαραίτητο μέγεθος δείγματος είναι της τάξης των 500 παρατηρήσεων κάτι που από πλευράς δεδομένων της πραγματικής οικονομίας είναι αδύνατον να είναι διαθέσιμο.

Πίνακας 4: Αριθμός στάσιμων σειρών ARMA(1,1) για τις οποίες η ασυμπωτική διακύμανση του $\hat{K}_P$ εκτιμώμενη σε πεπερασμένα δείγμα είναι αρνητική. [Συνολικός αριθμός σειρών για στάσιμο ARMA(1,1) που παρήχθησαν μέσω προσομοιώσεων Monte-Carlo ήταν 20000].

		Μέγεθος Δείγματος								
ρ_1=0.56		**n=5**	**n=10**	**n=20**	**n=30**	**n=40**	**n=50**	**n=60**	**n=80**	**n=100**
ARMA(1,1)	P=0.2	650	119	14	3	0	0	0	0	0
	P=0.3	806	100	8	0	0	0	0	0	0
	P=0.4	921	87	3	0	0	0	0	0	0
	P=0.5	997	85	2	0	0	0	0	0	0
	P=0.6	921	87	3	0	0	0	0	0	0
	P=0.7	806	100	8	0	0	0	0	0	0
	P=0.8	650	119	14	3	0	0	0	0	0
	P=0.99	367	178	39	5	1	0	0	0	0

Πίνακας 5: Καλύψεις των εκτιμηθέντων ασυμπτωτικών διαστημάτων εμπιστοσύνης για εκατοστημόρια σε 20000 στάσιμες σειρές AR(1) and ARMA(1,1) που παρήχθησαν μέσω προσομοιώσεων Monte-Carlo. Το ονομαστικό επίπεδο εμπιστοσύνης είναι 95%

ρ_1=0.56		**n=5**	**n=10**	**n=20**	**n=30**	**n=50**	**n=100**	**n=200**	**n=500**	**n=1000**	**n=2000**
P=0.5	ARMA	0.64	0.78	0.86	0.89	0.91	0.93	0.94	0.94	0.95	0.95
	AR	0.56	0.73	0.83	0.87	0.90	0.92	0.93	0.94	0.95	0.95
P=0.6	ARMA	0.64	0.78	0.86	0.89	0.91	0.93	0.94	0.94	0.95	0.95
	AR	0.56	0.73	0.83	0.87	0.90	0.92	0.94	0.94	0.95	0.95
P=0.8	ARMA	0.64	0.78	0.86	0.89	0.91	0.92	0.94	0.95	0.95	0.95
	AR	0.59	0.74	0.83	0.87	0.89	0.92	0.94	0.94	0.95	0.95
P=0.95	ARMA	0.62	0.76	0.85	0.88	0.91	0.92	0.94	0.94	0.95	0.95
	AR	0.61	0.73	0.82	0.86	0.89	0.91	0.93	0.94	0.95	0.95
P=0.99	ARMA	0.61	0.74	0.84	0.87	0.90	0.92	0.94	0.94	0.95	0.95
	AR	0.60	0.72	0.81	0.85	0.88	0.91	0.93	0.94	0.95	0.95

Παρατηρώντας επίσης τα στοιχεία του Πίνακα 6 βλέπουμε ότι για κάθε μέγεθος δείγματος, το REHL είναι μικρότερο στο ARMA(1,1) όταν ο θεωρητικός συντελεστής αυτοσυσχέτισης 1ης τάξης και των δυο υποδειγμάτων είναι ο ίδιος. Επίσης, για κάθε υπόδειγμα, το REHL βαίνει μειούμενο όσο αυξάνεται το P έως κάποια τιμή του μεταξύ του 0.6 και 0.8, και στη συνέχεια αυξάνεται και πάλι.

Πίνακας 6: REHLs των εκτιμηθέντων ασυμπτωτικών διαστημάτων εμπιστοσύνης για εκατοστημόρια σε 20000 στάσιμες σειρές AR(1) and ARMA(1,1) που παρήχθησαν μέσω προσομοιώσεων Monte-Carlo. Το ονομαστικό επίπεδο εμπιστοσύνης είναι 95%

ρ_1=0.56		**n=10**	**n=20**	**n=30**	**n=50**	**n=100**	**n=200**	**n=500**	**n=1000**	**n=2000**
R=0.2	ARMA	0.1855	0.1601	0.1383	0.1116	0.0814	0.0587	0.0374	0.0266	0.0188
	AR	0.1915	0.1716	0.1516	0.1246	0.0923	0.0669	0.0429	0.0305	0.0216
R=0.6	ARMA	0.1316	0.1141	0.0991	0.0802	0.0586	0.0423	0.0270	0.0191	0.0136
	AR	0.1371	0.1246	0.1105	0.0910	0.0674	0.0489	0.0314	0.0223	0.0158
R=0.7	ARMA	0.1300	0.1126	0.0976	0.0789	0.0576	0.0415	0.0265	0.0188	0.0133
	AR	0.1351	0.1221	0.1081	0.0890	0.0659	0.0478	0.0306	0.0218	0.0154
R=0.8	ARMA	0.1321	0.1140	0.0985	0.0795	0.0580	0.0418	0.0266	0.0189	0.0134
	AR	0.1363	0.1221	0.1079	0.0887	0.0657	0.0476	0.0305	0.0217	0.0154
R=0.9	ARMA	0.1393	0.1195	0.1029	0.0828	0.0603	0.0434	0.0277	0.0196	0.0139
	AR	0.1423	0.1259	0.1110	0.0910	0.0673	0.0488	0.0313	0.0222	0.0157
R=0.99	ARMA	0.1647	0.1395	0.1194	0.0957	0.0695	0.0499	0.0318	0.0226	0.0160
	AR	0.1647	0.1428	0.1252	0.1023	0.0755	0.0547	0.0350	0.0249	0.0176

Λαμβάνοντας λοιπόν υπόψη τις παραπάνω διαπιστώσεις για τις ιδιότητες των ασυμπτωτικών διαστημάτων εμπιστοσύνης όταν αυτά εκτιμώνται σε πεπερασμένα δείγματα, μπορούμε να ισχυριστούμε ότι τα διαστήματα εμπιστοσύνης για τα εκατοστημόρια της οριακής κατανομής των εκπομπών διοξειδίου του άνθρακα τα οποία δόθηκαν στο προηγούμενο τμήμα είναι έγκυρα. Καταρχάς, βλέποντας ότι οι εκτιμηθέντες συντελεστές αυτοσυσχέτισης $1^{ης}$ τάξης για τα δύο υποδείγματα είναι σχετικά κοντά στη τιμή $\rho_1 = 0.56$, μπορούμε να ισχυριστούμε ότι η απώλεια επι της % από το ονομαστικό επίπεδο εμπιστοσύνης 95% θα κυμαίνεται περίπου στο 5%.

Επιπλέον, για το κάθε υπόδειγμα, οι μεταβολές που παρατηρούνται στο REHL στις προσομοιωμένες σειρές όταν αυξάνεται το Ρ είναι ακριβώς οι ίδιες με αυτές που παρατηρούνται από τα πραγματικά δεδομένα της σειράς των εκπομπών διοξειδίου του άνθρακα. Το ότι το REHL εμφανίζεται μικρότερο στο AR(1), αυτό οφείλεται στο γεγονός ότι στο AR(1) ο εκτιμηθείς συντελεστής αυτοσυσχέτισης $1^{ης}$ τάξης είναι μεγαλύτερος από τον αντίστοιχο συντελεστή στο ARMA(1,1). Τέλος, και στα δυο εκτιμηθέντα υποδείγματα, οι επιπτώσεις της μη κανονικότητας των σφαλμάτων πάνω στην εγκυρότητα των διαστημάτων εμπιστοσύνης θα το παραπέμψουμε ως θέμα μελλοντικής έρευνας.

5. ΣΥΜΠΕΡΑΣΜΑΤΑ

Στην εργασία αυτή ασχοληθήκαμε με θέματα εκτιμητικής εκατοστημορίων όταν η διαχρονική εξέλιξη της υπό μελέτη μεταβλητής καθορίζεται από τη γενική γραμμική ανέλιξη ειδικές περιπτώσεις της οποίας είναι τα στάσιμα υποδείγματα AR(1) και ARMA(1,1). Χρησιμοποιώντας τον εκτιμητή μεγίστης πιθανοφάνειας, εξάγουμε την ασυμπτωτική του κατανομή και δίνουμε τη γενική μορφή του αντίστοιχου ασυμπτωτικού διαστήματος εμπιστοσύνης για την πραγματική τιμή του εκατοστημορίου. Ειδικές μορφές του ασυμπτωτικού αυτού διαστήματος πήραμε για τα στάσιμα AR(1) και ARMA(1,1).

Την εγκυρότητα του ασυμπτωτικού διαστήματος όταν αυτό εκτιμάται σε πεπερασμένα δείγματα ελέγξαμε σε στάσιμες σειρές AR(1) και ARMA(1,1) τις οποίες παράγαμε μέσω προσομοιώσεων Monte Carlo. Ας σημειωθεί εδώ ότι οι παράμετροι των δύο υποδειγμάτων επιλέχθηκαν έτσι ώστε η οριακή κατανομή των δυο υποδειγμάτων να έχει τον ίδιο μέσο και την ίδια διακύμανση καθώς και ο θεωρητικός συντελεστής αυτοσυσχέτισης 1^{ης} τάξης να είναι ο ίδιος και ίσος με 0.56. Σε ονομαστικό επίπεδο εμπιστοσύνης 95% βρήκαμε ότι με δείγμα τουλάχιστον 50 παρατηρήσεων το εκτιμημένο διάστημα εμπιστοσύνης επιτυγχάνει πραγματικό επίπεδο εμπιστοσύνης τουλάχιστον 90%. Επίσης με την αύξηση της αθροιστικής πιθανότητας που συνδέεται με το εκάστοτε εκατοστημόριο παρατηρήσαμε ότι το αναμενόμενο πλάτος του διαστήματος διαιρούμενο με την πραγματική τιμή του εκατοστημορίου στην αρχή μειώνεται και μετά αυξάνεται, με το ελάχιστο να συμβαίνει όταν η αθροιστική πιθανότητα βρίσκεται μεταξύ του 0.6 και του 0.8.

Έχοντας διαθέσιμη τη σειρά που αναφέρεται στην πυκνότητα των εκπομπών διοξειδίου του άνθρακα (CO_2, σε κιλά ανά ισοδύναμο κιλό πετρελαίου) στην Ελλάδα από το 1961 έως το 2010 και εφαρμόζοντας κατάλληλους στατιστικούς ελέγχους καταλήξαμε ότι ο στοχαστικός νόμος που έχει παράγει τις τιμές της μεταβλητής αυτής είναι είτε το στάσιμο AR(1) είτε το στάσιμο ARMA(1,1). Στην σειρά αυτή εφαρμόσαμε τη μεθοδολογία εκτίμησης του ασυμπτωτικού διαστήματος εμπιστοσύνης δίνοντας ξεχωριστά για το AR(1) και ξεχωριστά για το ARMA(1,1) το κάτω και πάνω όριο του εκτιμηθέντος ασυμπτωτικού διαστήματος εμπιστοσύνης για διαφορετικές τιμές της αθροιστικής πιθανότητας του εκατοστημορίου.

Από τα ευρήματα του ελέγχου αξιοπιστίας των εκτιμηθέντων ασυμπτωτικών διαστημάτων εμπιστοσύνης μέσω των πειραμάτων προσομοίωσης καταλήξαμε ότι τα διαστήματα εμπιστοσύνης για εκατοστημόρια για την υπό μελέτη μεταβλητή είναι έγκυρα. Το μόνο πρόβλημα που ανέκυψε στην εφαρμογή ήταν η ισχυρή ένδειξη της μη κανονικότητας των σφαλμάτων στα εκτιμηθέντα AR(1) και ARMA(1,1). Σε τι έκταση η μη κανονικότητα των σφαλμάτων επηρρεάζει την εγκυρότητα των εκτιμηθέντων ασυμπτωτικών διαστημάτων εμπιστοσύνης σε δείγματα τουλάχιστον 50 παρατηρήσεων και με μέτρια επίπεδα αυτοσυσχέτισης χρήζει περαιτέρω διερεύνησης.

ΠΑΡΑΡΤΗΜΑ: **Απόδειξη Λήμματος 1.**

Η στοχαστική ανέλιξη της σχέσης (1) εναλλακτικά γράφεται ως

$$X_t = \mu + \lim_{M\to\infty}\sum_{s=0}^{2M}\psi_s\varepsilon_{t-s}\,. \tag{A1}$$

Χρησιμοποιώντας τους μετασχηματισμούς $\psi_s = \beta_{s-M}$ και $\varepsilon_t = e_{t+M}$ (Fuller, 1996, σελ. 22), το δεξί σκέλος της (A1) παίρνει τη μορφή

$$X_t = \mu + \lim_{M\to\infty}\sum_{s=-M}^{M}\beta_s e_{t-s} = \mu + \sum_{s=-\infty}^{\infty}\beta_s e_{t-s}\,, \tag{A2}$$

με $\{e_t\}$ ανεξάρτητες τυχαίες μεταβλητές κατανεμόμενες ως $N(0,\sigma^2)$ και

$$\sum_{s=-\infty}^{\infty}|\beta_s| = \lim_{M\to\infty}\sum_{s=-M}^{M}|\beta_s| = \lim_{M\to\infty}\sum_{s=0}^{2M}|\psi_s| = \sum_{s=0}^{\infty}|\psi_s| < \infty\,. \tag{A3}$$

Η απόδειξη του τμήματος (α) του Λήμματος 1 ολοκληρώνεται χρησιμοποιώντας το θεώρημα 8.4.1 του Anderson (1971, σελ. 478), το οποίο επαναδιατυπώνεται ως εξής:

Εάν $X_t = \mu + \sum_{s=-\infty}^{\infty}\beta_s e_{t-s}$ όπου $\{e_t\}$ ανεξάρτητες μεταβλητές που έχουν την ίδια κατανομή με $E(e_t)=0$, $E(e_t^2)=\sigma^2$, και $\sum_{s=-\infty}^{\infty}|\beta_s| < \infty$, τότε το στατιστικό $\sqrt{n}(\overline{X}-\mu)$ ασυμπτωτικά κατανένεται κανονικά με μέσο μηδέν και διακύμανση $\sum_{s=-\infty}^{\infty}\gamma_s = \gamma_o\sum_{s=-\infty}^{\infty}\rho_s$.

Για την απόδειξη του τμήματος (β) του Λήμματος 1, θα χρησιμοποιήσουμε τις σχέσεις (A1)- (A3) και το θεώρημα 8.4.2 του Anderson (1971, σελ. 478): Εάν $X_t = \mu + \sum_{s=-\infty}^{\infty}\beta_s e_{t-s}$ όπου $\{e_t\}$ ανεξάρτητες μεταβλητές που έχουν την ίδια κατανομή με $E(e_t)=0$, $E(e_t^2)=\sigma^2$, $E(e_t^4)=3\sigma^4+\kappa_4<\infty$, και $\sum_{s=-\infty}^{\infty}|\beta_s| < \infty$, τότε το διάνυσμα

$$\sqrt{n}\left[\hat{\gamma}_o-\gamma_o \quad \hat{\gamma}_1-\gamma_1 \quad \hat{\gamma}_2-\gamma_2 \quad ,..., \quad \hat{\gamma}_{n-1}-\gamma_{n-1}\right]'$$

ασυμπτωτικά ακολουθεί την n–διαστάσεων κανονική κατανομή με μέσο **0** και μήτρα διακυμάνσεων-συνδιακυμάνσεων που προκύπτει από τη σχέση

$$\lim_{n\to\infty} n\mathrm{Cov}(\hat{\gamma}_h,\hat{\gamma}_g) = \sum_{s=-\infty}^{\infty}\left[\gamma_{s+h}\gamma_{s+g}+\gamma_{s-g}\gamma_{s+h}\right] + \frac{\kappa_4}{\sigma^4}\gamma_h\gamma_g,\quad h=0,1,...,n-1\ ,\ g=0,1,...,n-1, \tag{A4}$$

όπου $\hat{\gamma}_h = \frac{1}{n-h}\sum_{t=1}^{n-h}(X_t-\mu)(X_{t+h}-\mu)$, και $\kappa_4 = E(e_t^4)-3\sigma^4$ είναι το 4ης τάξης cumulant.

Όταν $e_t \sim N(0,\sigma^2)$ τότε $\kappa_4 = 0$, οπότε θέτοντας $h=g$ στη σχέση (A4) το στατιστικό $\sqrt{n}(\hat{\gamma}_o-\gamma_o)$ ασυμπτωτικά θα έχει τη κανονική κατανομή με μέσο 0 και διακύμανση

$$2\sum_{s=-\infty}^{\infty}\gamma_s^2 = 2\gamma_o^2\sum_{s=-\infty}^{\infty}\rho_s^2\,.$$

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Exploring climate change issues related to water resources and agriculture in Cyprus, employing a Delphi type method

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Abstract
Climate change and agriculture are interrelated processes, both of which take place on a global scale. Cyprus is already experiencing the impacts of climate change on agricultural production with reduction in precipitation droughts and increasing temperatures. Assessment of the effects of global climate change on agriculture might help to properly anticipate and adapt farming to maximize agricultural production. The main aim of this paper is to identify and quantify impacts of climate change on the Cypriot agricultural sector. In order to do this, foresight information from a structural survey were used; the survey made use of the intuitive available knowledge and information of the experts participated in the survey. Specifically, a Delphi type multi round interactive survey method has been employed, using willingness to pay values from repetitive surveying of experts, during May and June 2011. The Delphi method has been applied to rank and quantify several impacts of climate change according to the literature. Using this method the several impacts of climate change on crop production and water resources allowed to be brought into the modeling effort on equal footing with cost values. When the subject matter is concisely defined and limited, this technique can rapidly assess expert opinion on any natural resource issue, and even move expert opinion toward greater agreement. The final cost of the impact represents the total cost of climate change. According to the results of the analysis this cost reaches to an annual amount of €74 million for the agricultural community and €248 million for the total population. Therefore, it is expected that in the seven-year programming period 2014-2020 the total cost of climate change on agriculture will reach from €518 to €1,736 million. It is worth noting that the most significant impact refers to the increasing level of CO_2 in the atmosphere and the burden of biodiversity and ecosystems, while the less significant impacts refer to the variability in productivity and diversification of agricultural production and trade of agricultural products. One could say that this is the cost of adapting to climate change, but generally adjustment costs to avoid even higher future costs due to mismanagement of water resources.

Keywords: Agriculture; Climate change; Delphi Method; Impacts; Water resources; Willingness to Pay.

JEL codes: O13; Q51; Q54.

1. Introduction

Like other Mediterranean countries, Cyprus has a semi-arid climate with mild, wet winters (mean daily minimum 5^{o}C) and hot, dry summers (mean daily maximum 36^{o}C) while also associated with limited water resources (Hadjinicolaou et al., 2001). The principal cause of water scarcity is the combination of limited availability and excess demand of water among competing uses; this is clearly illustrated by the fact that Cyprus has the highest Water Exploitation Index (45%) in the EU (EEA, 2009) - which becomes much higher in years of excessive drought. Historically droughts occur every two to three consecutive years as a result of large inter-annual decreases in precipitation. In the last four decades however, drought incidences have increased both in magnitude and frequency (Papasozomenou and Zikos, 2009).

Water management has been problematic since the 1960s due to the limited development of water infrastructure for domestic and irrigation supply (Papadavid et al., 2011). According to Markou et al. (2011), the national government's top priorities were to ensure food security and constant supply of good quality water so that the adverse effects of water scarcity do not impede socioeconomic development, given that agriculture was the backbone of the economy, contributing by about 20% to the country's GDP. As Cyprus gradually became service-dominated, the contribution of agriculture has decreased dramatically, and currently accounts for about 2% of GDP and 7% of the total workforce. Despite such decreases, agriculture still remains the dominant water user in the country, accounting for 69% of total water use, while the domestic sector accounts for 25% - of which one fifth goes to tourism. In order to store as much freshwater as possible, Cypriot governments have constructed numerous dams on key catchments in the course of the years. As a result, the water storage capacity of the island increased from 6 million cubic meters in 1960 to 327 million cubic meters in 2009, making Cyprus one of the most developed countries in terms of dam infrastructure (Zachariadis, 2010).

The relationship between climate and agriculture is usually not one way (Alston and Whittenbury, 2013). Agriculture has the potential to influence and shape the climate at local, regional and global scale (Moore and Ghahramani, 2014). In particular, irrigation, natural growth of cultivated species and plant cover rate, determine the levels of available soil moisture and indirect the transfer of heat, moisture and momentum rising from the ground into the atmosphere. Therefore, agriculture affects the existence, the location and the intensity of heat transfer and water vapor, and participates in setting the global climate. Besides, agriculture in the broadest sense (including livestock production), is an activity which emits some of the greenhouse gases, contributing this way to the acceleration of climate change.

Climate change is the indirect result of a combination of a large number of human activities and natural changes (Markou et al., 2011). Climate change is a challenge but also a threat to sustainable agricultural development at the local and global level. Although agriculture in the broadest sense, is a complex and well developed sector, it is expected to be directly affected by climate change, because temperature, sunlight and water are the main factors of crops growth. It is estimated that the effects of climate change will make agriculture activities from high uncertainty in high risk activities.

Due to severe droughts occurred in Cyprus in the years 1990/1991 and 1996/2001 the whole of the island was under stress with obvious threats on the ecosystem. The reduced Rainfall deprived the satisfactory irrigation of forests, and of rain fed agriculture; surface runoff was reduced with reduced inflows to dams and wetlands; Wetlands did not collect enough water with adverse effects on their biodiversity; Recharge of the aquifers was less than normal and aquifers were over pumped to satisfy normal demand resulting to groundwater mining; Domestic water supply was reduced endangering quality of life and sanitation of the citizens; Water for irrigation was reduced with social, economic, and environmental adverse effects; Dry lands posed a thread for fires and uncontrolled fires destroyed great areas resulting to environmental disasters (Tsiourtis, 2002).

Climate is one of the most important factors determining the productivity of farming systems (Thierfelder et al., 2014). The foundation of the quantity and quality of agricultural production is the optimal degree of harmonization between the traits of crop species, the cultivation practices and the local climate and environment. It is apparent that, every aspect of agricultural activity is affected by the climate and it is also required the continuous adaptation of agriculture to a wide range of factors. Therefore, to allow the maintenance of satisfactory standards of production in the future interventions to promote, inter alia, the adaptation of agriculture to the parameters that characterize directly or indirectly the climate change, like global warming, the increase of the concentration of CO_2, drought, flooding, salinization of soils, etc, should be targeted.

The main aim of this paper is to identify and quantify impacts of climate change on the Cypriot agricultural sector. In order to do this, foresight information from a structural survey were used; the survey made use of the intuitive available knowledge and information of the experts participated in the survey. Specifically, a Delphi type multi round interactive survey method has been employed, using willingness to pay values (WTP) from repetitive surveying of experts, during May and June 2011. The WTP is used to estimate economic values for all kinds of ecosystem and environmental services. The method allows better valuation of non-market goods and services than any other non-market valuation technique (Lim et al., 2014). It can be used to estimate both use and non-use values, and it is the most widely used method for estimating non-use values (Husted et al., 2014). The WTP involves directly asking people, in a survey, how much they would be willing to pay, or the amount of compensation they would be willing to accept to give up, for specific environmental services. The WTP is referred to as a “stated preference” method because it asks people to directly state their values, rather than inferring values from actual choices, as the “revealed preference” methods do. The fact that WTP is based on what people say they would do, as opposed to what people are observed to do, is the source of its greatest strengths and its greatest weaknesses. However, WTP is one of the only ways to assign price values to non-use values of the environment-values that do not involve market purchases and may not involve direct participation (sometimes referred to as “passive use” values). WTP is employed in the present study as a secondary approach in assessing the cost of climate change on Cypriot agriculture and in quantifying the impacts of climate change.

2. Methodology

The principal aim of the current study is to measure in a scientific manner the cost of climate change on Cypriot agriculture. In order to achieve this target this paper employees a quantitatively Delphi method using expert's WTP values. Empirical analysis is based on a questionnaire: a) administered using e-mail, b) conducted, during May and June, in 2011 and c) addressed to 20 experts of climate change. This focus group mainly comprised of key stakeholders in Cyprus (academics, policy directors, staff scientists and farmers engaged climate change research).

The Delphi method mainly developed by Dalkey and Helmer (1963) and is a widely used and accepted method for achieving convergence of opinion concerning real-world knowledge solicited from experts within certain topic areas (Hsu and Sandford, 2007). Researchers have applied the Delphi method to a wide variety of situations as a tool for expert problem solving. However, in the literature only two papers can be found applying the Delphi method in climate change issues (Torres and Pina, 2011; Changnon, 1982). Thus, the contribution of this paper is twofold: a) from a methodological point of view this paper offers a research framework to quantify climate change impacts using WTP prices and b) from a practical point of view this papers estimates the cost of adapting to climate change, in order to avoid even higher future costs due to mismanagement of water resources and agriculture. The following figure 1 presents the general organization framework of the Delphi technique.

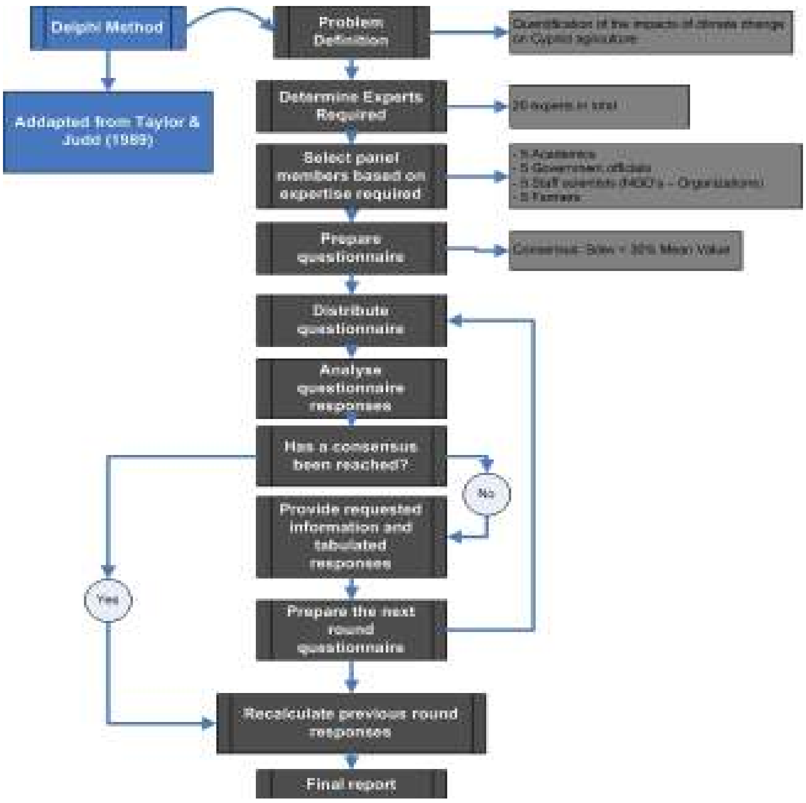

Figure 1: Organization of the Delphi process

2.1 Research questions and strategy

We wish to contribute to the growing body of work on the economic impact of climate change. Specifically, the research study investigates in a scientific manner the cost of climate change on Cypriot agriculture and water resources. In order to achieve this target we employ a research plan consisting of a three-step strategy. First, to identify

factors that will answer the research question. The second step involves quantitatively evaluating the identified factors. This is more objective and should provide more confidence and solid directions for the third step: repeating the data collection until the satisfaction of the consensus condition which was declared by the researchers.

2.2 Scope of the initial study

The academic literature provides some theoretical discussion related to the impacts of climate change on crop production and water resources offering some important and practicable recommendations. However, obtaining a more comprehensive view necessitates perspectives from all four major stakeholders in climate change reality: academics, policy directors, staff scientists and farmers engaged climate change research.

2.3 Selection of the Delphi methodology

Actually, a traditional survey could be used to gather input from a group of experts or stakeholders concerning climate change impacts. However, a Delphi method, and especially a quantitatively Delphi method, has been judged to be a stronger methodology for a rigorous query of experts for the following reasons (Okoli and Pawlowski, 2004):

A quantitatively Delphi study answers the complex study question more properly for the reason that this compound concern requires deep knowledge and practical experience from people who understand *in extenso* the different economic, environmental, agronomical, social and political issues.

A quantitatively Delphi study does not require the experts to meet physically.

A quantitatively Delphi study requires a limited number of experts.

A quantitatively Delphi study allows a deeper understanding of the complex research question mainly due to its flexibility to follow-up interviews.

A quantitatively Delphi study serves the dual purpose of ranking the climate change impacts according to their importance and having them evaluated using WTP values.

2.4 Procedure for selecting experts

Following the guidelines of Delbecq et al. (1975) and Okoli and Pawlowski (2004) this study employed a multiple-step procedure to categorize, identify and select the experts (Fig. 2).

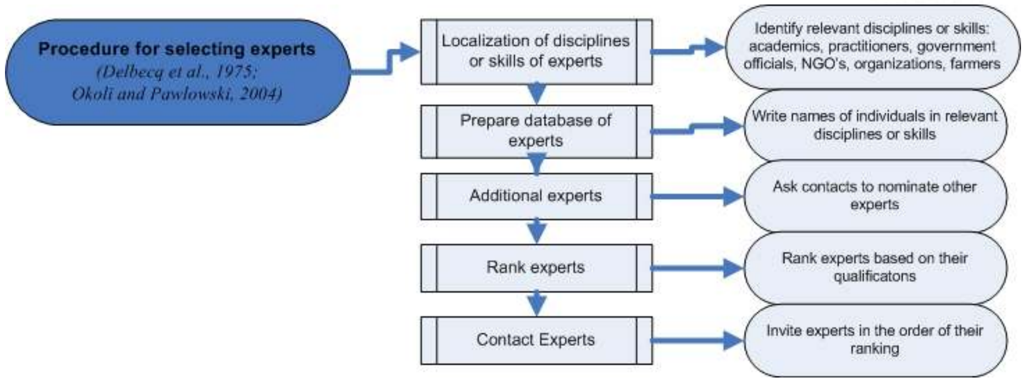

Figure 2: Procedure for selecting experts

2.5 Data collection and analysis method

The Delphi questionnaire has been administered using e-mail and following a modified version of the procedure for "ranking-type" Delphi studies outlined by Schmidt (1997). This general procedure basically involve three steps: brainstorming for important factors, narrowing down the original list to the most important ones and ranking the list of important factors. The employed modified version involves one more step; evaluating the most important factors using WTP values.

To address the research aim, the first version of the very simple questionnaire asked experts to list at least six important impacts of climate change on Cypriot agriculture. This creative process was designed to generate a list of climate change impacts, removing identical or similar responses, which we refer to as the climate change impacts list. Then, we sent this list to the heterogeneous group of experts asking them to mention additional impacts from the generated list and to validate that we have correctly interpreted their initial responses and placed them in an appropriate category. In a third stage the experts have been asked to rank the impacts of climate change based on their effects on agricultural activity. Finally, the experts have been asked to state their suppositional maximum WTP in order to avoid (on paper) each of these impacts. This final step has been repeated three times up to the satisfaction of the consensus condition which is that the standard deviation of the experts WTP values for each impact does not exceed the 30% of the mean WTP value of the impact. In any failure to satisfy the consensus condition each expert asked to mention new suppositional maximum WTP value closer to the respective mean WTP value (Fig. 3).

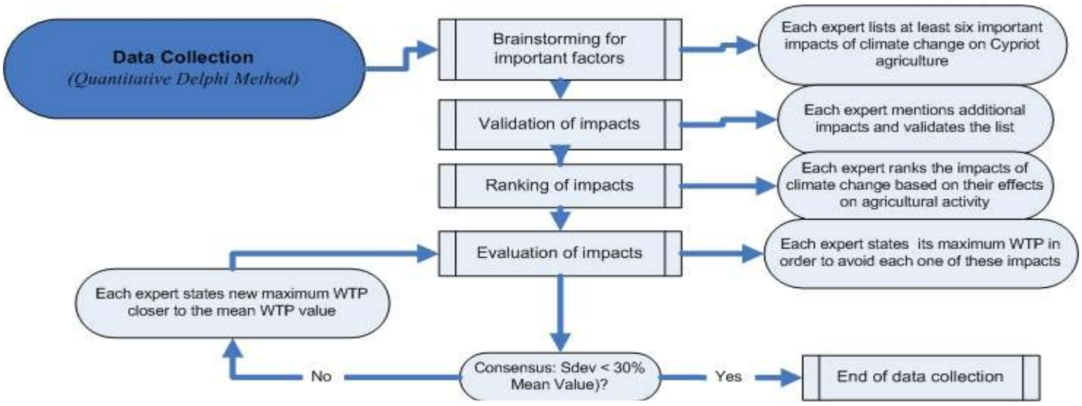

Figure 3: Data collection process

3. Results

Table 1 below summarizes the experts' rankings and the experts' valuation (first round) of external impacts of climate change, expressed in monetary units of maximum, minimum and mean annual WTP, as assessed using the hypothetical or dependent valuation, including the respective standard deviations. It is worth noticing that in almost all impacts the minimum value is zero while the mean ranged from 8.5 to 33 Euros. In all cases, both the minimum and maximum value, determined on the basis of standard deviation. Specifically, the maximum values were estimated as the sum of the average values and respective standard deviations, and minimum values as differences of average values and the corresponding standard deviations (in each case the minimum values must be greater than or equal to zero). Thus it is considered to achieve more representative evaluation since extreme values are avoided and the likelihood of too positive or too negative valuation WTP is limited.

Table 1: First round's maximum, mean and minimum WTP values (Euros)

Impacts of climate change	Max	Mean	Min	S.Dev.
Increasing of CO2 concentration	71.17	33.16	0.00	38.01
Burden on the environment, ecosystems and of biodiversity (loss of native species)	60.55	30.00	0.00	30.55
Increased fire incidents	59.68	29.15	1.38	29.15
Warming	54.82	24.21	0.00	30.61
Increased occurrence of diseases and pests	55.00	24.12	0.00	30.79
Increased frequency of extreme weather events	49.14	23.89	0.00	36.30
Intensity of competition in water use in agriculture	49.01	23.79	0.00	25.24
Increased spending on tackling the cost of irrigation water, appropriate propagation material, special fertilizers and damage from extreme weather phenomena	48.32	21.25	0.00	27.26
Burden of soil fertility and erosion	48.72	21.05	0.00	27.67
Increase in price of agricultural products	44.30	18.42	0.00	25.88
Variation in rainfall	44.66	17.47	0.00	27.19
Reduction of farm income	40.36	15.79	0.00	24.57
Change in productivity and yields	22.24	8.95	0.00	13.29
Diversification of agricultural production and agricultural trade	23.07	8.47	0.00	14.60

However the consensus condition has not been satisfied in the first round. Thus, the data collection repeated in a second (and third round) by asking experts to mention new suppositional maximum WTP value closer to the respective mean WTP value of the previous round. After three rounds the data collection procedure has been completed as the standard deviation of the experts WTP values for each impact did not exceed the 30% of the mean WTP value of the impact (Fig. 4).

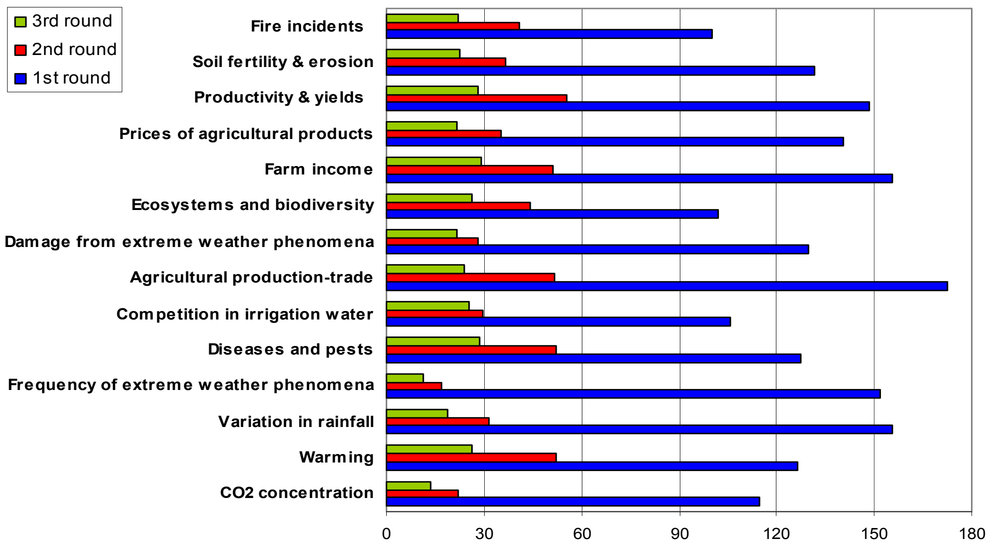

Figure 4: Satisfaction of consensus concept (after 3 rounds)

Table 2: Third round's maximum, mean and minimum WTP values (Euros)

Impacts of climate change	Max	Mean	Min	S.Dev.
Increasing of CO2 concentration	37.14	32.66	28.17	4.49
Burden on the environment, ecosystems and of biodiversity (loss of native species)	39.34	31.11	22.88	8.23
Increased fire incidents	34.47	27.52	20.56	6.96
Warming	32.19	25.01	17.82	7.19
Increased occurrence of diseases and pests	31.14	24.63	18.11	6.52
Increased frequency of extreme weather events	30.09	24.62	19.14	5.48
Intensity of competition in water use in agriculture	27.13	24.41	21.68	2.73
Increased spending on tackling the cost of irrigation water, appropriate propagation material, special fertilizers and damage from extreme weather phenomena	26.75	22.00	17.24	4.76
Burden of soil fertility and erosion	25.51	20.84	16.17	4.67
Increase in price of agricultural products	22.17	18.66	15.14	3.52
Variation in rainfall	22.48	18.46	14.44	4.02
Reduction of farm income	21.71	16.82	11.93	4.89
Change in productivity and yields	11.8	9.52	7.23	2.29
Diversification of agricultural production and agricultural trade	12.19	9.50	6.8	2.70

Table 2 below presents the final experts' rankings and the experts' valuation (third round) of external impacts of climate change. The mean WTP values ranged from 9.5 to 33 Euros. An important observation is that after 3 rounds the mean WTP values did not change significantly although the maximum and minimum values change approaching significantly the mean and limiting the standard deviation.

The following Figures 5, 6 and 7 present graphically the quantification of the 14 impacts of climate change to Cypriot agriculture using the mean values of expert's WTP. Very small changes have been observed in the three figures as the sum of the mean effects of climate change in all rounds ranged from around 300 to 311 Euros.

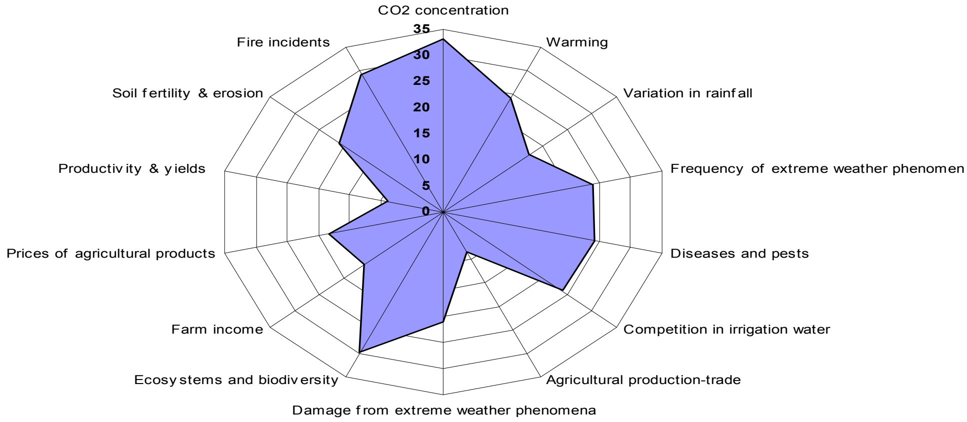

Figure 5: First round of Delphi process (mean WTP values)

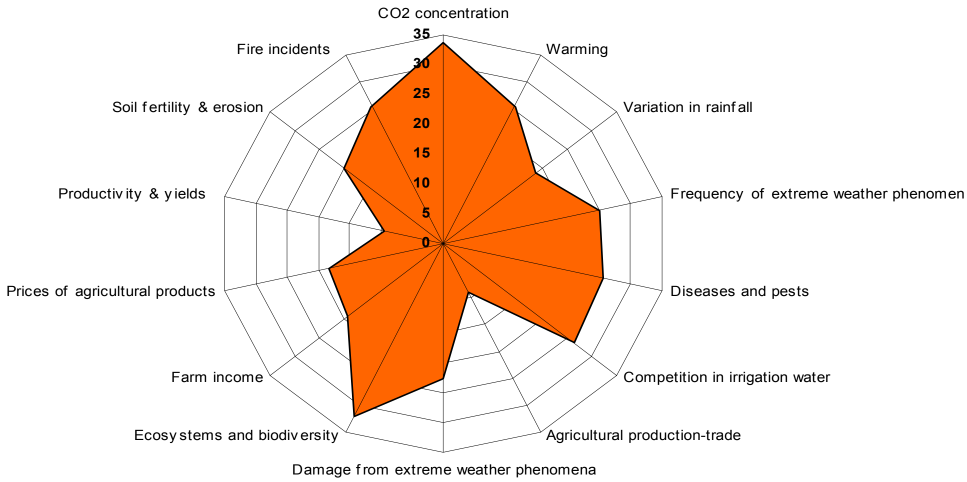

Figure 6: Second round of Delphi process (mean WTP values)

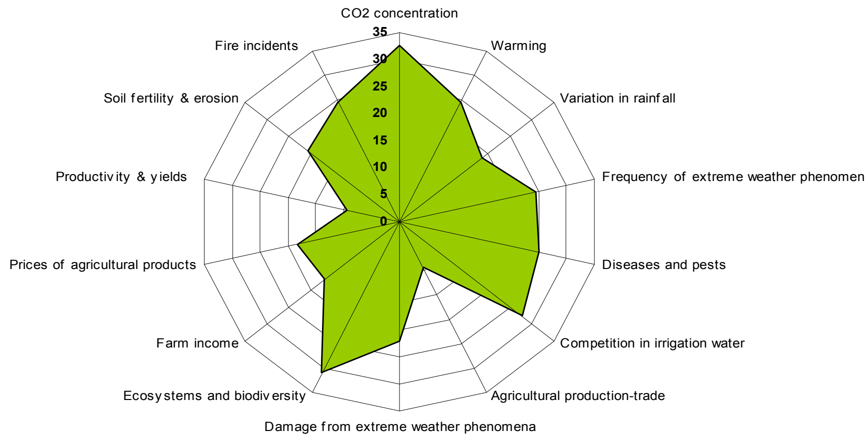

Figure 7: Third round of Delphi process (mean WTP values)

Table 3: Reduction of the estimations of climate change impacts (in euros)

Impacts of climate change	Reduction to the Agricultural population	Reduction to the whole population
Increasing of CO2 concentration	7,948,452	26,634,112
Burden on the environment, ecosystems and of biodiversity (loss of native species)	7,191,000	24,096,000
Increased fire incidents	7,119,090	23,855,040
Warming	6,987,255	23,413,280
Increased occurrence of diseases and pests	5,803,137	19,445,472
Increased frequency of extreme weather events	5,745,106	19,251,017
Intensity of competition in water use in agriculture	5,726,433	19,188,448
Increased spending on tackling the cost of irrigation water, appropriate propagation material, special fertilizers and damage from extreme weather	5,669,169	18,996,564
Burden of soil fertility and erosion	5,045,685	16,907,360
Increase in price of agricultural products	4,415,274	14,794,944
Variation in rainfall	4,187,559	14,031,904
Reduction of farm income	3,784,863	12,682,528
Change in productivity and yields	2,145,315	7,188,640
Diversification of agricultural production and agricultural trade	2,030,259	6,803,104

However, a higher value has the following table 3 which includes the reduction of the average values of each effect in both the agricultural community and the total population (agricultural and non agricultural) of the research area. The final sum of the impacts in this table represents the total cost of climate change which amounts to €74 million for the agricultural population and €247.97 million for the total population. It is worth noting that the most significant impact refers to the increasing of CO_2 amount in the atmosphere and the burden of biodiversity and ecosystems, while a less significant impact is considered the variability of productivity and diversification of agricultural production and agricultural products trade.

4. Conclusions

The main concern in this paper is the importance of a common understanding between the actors involved in climate change impacts to water resources and agriculture in Cyprus. Although, the ranking-type Delphi method has been used by researchers for almost three decades there are several areas for improvement, such as quantification of the answers. Our listing of attributes provides a framework that we intend to be helpful to researchers as well as journal reviewers and editors. The present study has several implications, both theoretical and practical, since its empirical results support the basic argument of the paper that climate change causes significant changes in irrigation management and Cypriot agriculture. Concluding, we believe that the more detailed analysis of climate change impacts sheds light on the structural changes in Cypriot agriculture, but also on the principles and mechanisms that enable these changes. Such results will advance the conceptual framework in the agricultural sciences and economics and may result in new approaches to agricultural policy.

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Managing environmental services as a renewable resource[36]

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Abstract
In this paper, the basic assumption is that the environment provides two different kinds of services. First, the environment may serve as an input to the production of conventional goods. For example, the exploitation of an oil source from which one firm extracts the oil which in turn is used as a fossil fuel for an industry. In the worst case, the use of the environment for industrial purposes will negatively affect the environment, e.g. the water quality of a paper mill along a river. Nevertheless, the possibility to pollute, i.e., to save abatement costs, lowers production costs. Hence, firms and consumers evaluate this service positively. Second, the environment itself—clean air, natural creeks and rivers instead of paper mills, hydro power plants, etc.—provides amenities and thus a second service, that is different, because enjoying this service does not degrade environmental quality. As it is intuitive clear, the environment provides consumptive and non-consumptive uses. In renewable resources means, the environmental stock may be harvested and used as an input for conventional goods' production but provides simultaneously a positive externality. The purpose of this paper is to study the dynamics of pollution and the possibility of cycles and instability, while the major finding of this paper is the following: Taking the simplest pollution model with one state and one control variables and extending it into two state variables, equilibrium may change from the fixed point into a limit cycle equilibrium, i.e. the optimal emissions rate may be cyclical.

Keywords: Environment; renewable resources; environmental economics.
JEL codes: C61; C62; D43; H21.

1. Introduction

Analyzing pollution control issues for developed and developing countries has become an important multi–disciplinary topic. Since the design of efficient action against pollution has to take into consideration the intertemporal response of victims, dynamic modeling can be used as an appropriate tool. In this paper we make two basic assumptions. The first is that the environment provides two different kinds of services. i.e., the environment may serve as an input to the production of conventional goods and second, the environment itself provides amenities. In the second assumption the damage function is

[36] This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: Thalis – Athens University of Economics and Business -*"Optimal Management of Dynamic Systems of the Economy and the Environment"*

depending on the intensity of emissions and on the intensity of abatement as well.
We use both optimal control and differential game approaches to study the intertemporal strategic interactions between the polluters and the social planer.

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The pollutants accumulation is a major problem in our world and finding a way to effectively reduce, while maintaining the standards of the production process, is a great challenge facing capitalistic societies. The clean environment is obviously a public good. Conversely, all the "dirty" production process that creates pollutants accumulation, e.g. emissions caused by uncontrolled production, constitutes a public bad. But which of the factors of production process generates pollutants? Clearly uncontrolled, with respect to the environment, production involves antiquated equipment that emits more than permissible and therefore constitutes a polluters' "bad weapon". It is a usual phenomenon the old production equipment - which used to be the main production equipment for the Western developed countries - to change hands moving to the Southern or Eastern developing countries at a low acquisition cost. Similarly, all the extracted depletable resources which are used as inputs in the production are sources of pollution. The power of such a "dirty" production process rests upon the accumulation of a stock of resources, consequently depending on the financial capital for these resources that emits more and therefore accumulates pollutants.

On the other hand, in early days of applications of dynamic systems to economic problems, it was recognized that the optimal solution of infinite time problems may be characterized by multiple equilibrium points. Finding multiple equilibrium points in economic models is not an attractive solution for the policy makers. But the recognition of multiple optimal stable equilibria may be crucial in order to locate the thresholds separating the basins of attraction surrounding these different equilibria. Starting at a threshold, a rational economic agent is indifferent between moving toward one or the other equilibrium, but a small movement away from the threshold can "destroy" this indifference, leading in a unique optimal course of action.

Since the introductory one sector, with a convex – concave production function, optimal growth model of Skiba (Skiba, 1978), there has been a lot of progress towards the cyclical solution strategies generated in intertemporal dynamic economic models. Wirl (1995) exploring the optimality of cyclical exploitation of renewable resources stocks, reconsidering a model of Clark *et al* (1979), concludes that equilibrium that falls below the maximum sustainable yield but that exceeds the intertemporal harvest rule due to the positive spillovers allows for optimal, long run, cyclical harvest strategies.

Limit cycles, according to Poincare–Bendixson condition (Hartman, 1982) which also restricted in planar systems, has the intuitive explanation which says that if a trajectory of a continuous dynamical system stays in a bounded region forever, it has to approach "something". This "something" is either a point or a cycle. So if it is not a point, then it must be a cycle. This gives rise to cyclical policies in economic models, e.g. if a policy trajectory, say an abatement pollution policy, is restricted in a bounded planar space then this policy sooner or later will retrace its previous steps.

The Poincare–Andronov–Hopf theorem (Kuznetsov, 2004), which applies in a higher than the two dimensional systems, gives sufficient conditions for the existence of limit cycles of nonlinear dynamical systems. Informally, one can think of this theorem as requiring that equilibrium must suddenly change from a sink to a source with variation of a parameter. Arithmetically this requires that a pair of purely imaginary eigenvalues exists for a particular value of the bifurcation parameter and that the real part of this pair of eigenvalues changes smoothly its sign as the parameter is altered from below its actual value to above.

Hence, analogously to equilibrium, the stability of limit cycles is of great importance for the long run behavior of a dynamical system. But since the existence and therefore stability of a limit cycle is highly dependent on an arbitrarily chosen bifurcation parameter we have to deal with the qualitative analysis of such a problem. Economic mechanisms that may be a source of limit cycles, as mentioned by Dockner and Feichtinger (1995) are: (i) complementarity over time, (ii) dominated cross effects with respect to capital stocks, and (iii) positive growth of equilibrium.

The main contribution of the paper is twofold: First, it considers the environment as a renewable resource for which the environmental quality grows with the pollutants abatement but reduces with the damages stemming from pollutants accumulation which in turn are treated as a stock. Having the two states, i.e. the environmental quality as a stock and the stock of pollutants the benevolent social planer has to steer the control variable, i.e. the emissions, in an optimal way between the two states, and this setting gives rise for complex polices especially for limit cycles. Second, it considers the pollution control problem, as a differential game in which two players involved. The first player is the polluting representative producer which maximizes his own utility stemming from emissions while the second player is every enjoyer of the environmental services, maximizing his own utility derived from the clean environment and from the pollutants abatement as well.

In both cases, we explore the Nash equilibrium and especially in the first case we investigate the existence of limit cycles and consequently the existence of cyclical strategies of the instrument variables. The environmental pollution control game takes place between the government, acting as the social planer, and polluters for which the resources used in production accumulate pollutants. Such pollutants accumulation and regulation control models can be found, among others, in Forster (1980) concerning optimal energy use model; in Xepapadeas (1992) regarding environmental policy design and non-point source pollution and so on.

The remainder of the paper is organized as follows. Section 2 introduces the social planer's optimal control model and gives a necessary condition for cyclical strategies.

Section 3 investigates the differential game between the government and the polluter and calculates the Nash equilibrium strategies and the players' value functions. Section 4 explores the limit cycle equilibrium of the management model, while section 5 introduces and solves analytically the proposed differential game. The last section concludes the paper.

2. The pollution management model

As it is known the production process accumulates pollutants and therefore all the owners of the productive assets, called the polluters, are always to some degree subject

to emissions constraints such that too low levels of pollutants will topple the regime. Of course, the precise magnitude depends on several international treaties e.g. the Kyoto or Montreal protocols, as well as on the inshore's institutions. However, even in development industrial countries a level below 50% mark is beneficial because of two things: first, the low level of pollutants per se provides fringe benefits, in the sense of a good reputation, and second discretionary power increases if the pollutants are abated, therefore the consumers will trust the abating firms. In the model below we introduce the function $V(T)$ which captures all kinds of benefits of a good environmental state such that $V(T)$ may become very negative if pollutants exceed a certain threshold.

Given the pollutants generating nature of production and the benefits accrued form a clean environment, the social planer of an economy has to steer very carefully between Scylla and Charybdis and this trade off may involve complex patterns over time, in particular, limit cycles. Formally, the social planer maximize the intertemporal benefits (and the implicit trade off) from a good as possible environmental state, by T we denote the environmental state, and from emissions, E denotes emissions in the production process. These two types of benefits are separable, $U(E(t))+V(T(t))$, in order to simplify the analysis and both utility functions are increasing and concave: $U'>0$, $U''<0$; $V'>0$, $V''\leq 0$. The emissions can be abated, i.e. its rate can become negative such that the central planer, in order to maintain a clean environment, engages in a crusade against pollution. This modeling of a soft constraint through the function of V instead of considering hard constraints $T(t)\geq \tilde{T}$[37] is chosen for three reasons. First, a hard constraint imposes a lexicographic preference ordering upon the environment which seems implausible. Second, the state of environment over and above the required threshold offers further and different kinds of benefits: a good state of the environment itself may be desirable, i.e. a consumption good; a high state offers to the central planer considerable discretion and so on. Third, this formulation guarantees smoothness of the solution and thus simplifies the analysis. Moreover, sufficient smoothness is a requisite to apply Hopf bifurcation theorem.

After all, the social planer faces the following problem:

[37] Where $\tilde{T}$ identifies the minimal state of the environment

$$\max_{E(t)} \int_0^{\infty} e^{-\rho t} \left[U\left(E(t)\right) + V\left(T(t)\right) \right] dt \tag{1}$$

subject to $\dot{T} = A(T) - D(S)$ (2)

$$\dot{S} = E - \delta S \tag{3}$$

E are emissions
S is the stock of pollutants
T is the state or quality of the environment
$A(T)$ is the growth of environmental quality, the natural replenishment or abatement
$D(S)$ are the loses or damages in environmental amenities depending on the pollution stock. In another way the same function should be the amount of input used by the industry.

Maximization (1) is subject to two dynamic constraints. First, the state of environment is a dynamic process, here is a diffusion process according to (2) – which is negatively affected by damages of environmental state, e.g. by the stock of pollutants S. However, environmental state is affected, by the large, not only from the isolated emissions but from the cumulative pollutants. The accumulated pollutants, according to differential equation (3), obey to the natural purification law, i.e. they have the exponential declining factor $\delta \geq 0$.

The function $A(T)$ may represent an arbitrary, but concave $\left(A'' < 0\right)$ process $A(T) = T(1-T)$. In the present model $A(T)$ rather represents the abatement. This specification is chosen because of its wide use in the literature, its plausibility and its convenience, but is not crucial for the model. Logistic growth, first proposed by Verhulst (1845), arising from the more general equation $\dot{x} = rx\left|1 - x/K\right|^{a} \operatorname{sign}\left(1 - x/K\right)$, where r the intrinsic growth, K the carrying capacity and a a positive constant playing the role of the penalty in a population model. Gatto *et al.* (1988) prove the optimality of the logistic growth function in both linear ($a = 1$) and nonlinear ($a \neq 1$) cases, and draw the optimal trajectories in both cases. Following population growth models it can be shown (Gatto et al, 1988), in absence of pollution, the optimal growth of environmental state is logistic. That is, since the abatement must be equivalent to the optimal growth, this function could be the logistic, i.e. abatement could be in the form: $A(T) = T(1-T)$

The function $D(S)$ measures the environmental degradation depending on the pollutants accumulation S. Thus, $D' > 0$ and we assume additionally, and quite plausibly, $D'' > 0$. Equation (3) is the standard equation of pollutants motion used in environmental models (see for example Dockner and Long, 1993).

In the solution process, we define the Hamiltonian (omitting arguments)

$$H = U + V + \lambda(A - D) + \mu(E - \delta S) \tag{4}$$

λ, μ are the costate variables of the states T and S respectively.

The Hamiltonian is concave in states and control, because the objective, as well as the state transition equations are concave, and the costate variable λ must be positive. The

Hamiltonian maximizing condition w.r.t. the control $E(t)$, i.e. w.r.t. the emissions, is the following:

$$H_E = U' + \mu = 0 \qquad (5)$$

and it is assumed that an interior solution exists, which is already the general case owing to the strict concavity of the Hamiltonian with respect to E, i.e. $H_{EE} = U''(E) < 0$.
We record the above result in a proposition.

Proposition 1: In the pollution management model (1) – (3) the intertemporal optimality requires the marginal utility from emissions equals to the negative of the shadow price of the stock of pollutants.
Proof
Follows immediately from the optimality condition (5)

Now, the following two equations determine the evolution of adjoints $\lambda,\ \mu$.

$$\dot{\lambda} = (\rho - A')\lambda - V' \qquad (6)$$

$$\dot{\mu} = (\rho + \delta) + \lambda D' \qquad (7)$$

The optimality conditions $(5)-(7)$ are valid only if additionally the limiting transversality conditions are satisfied:

$$\lim_{t\to\infty} e^{-\rho t}\lambda(t)T(t) = 0 \qquad (8)$$

$$\lim_{t\to\infty} e^{-\rho t}\mu(t)S(t) = 0 \qquad (9)$$

3. Stability analysis

For interior solutions the Hamiltonian maximizing condition allow to replace the control variable $E(t)$ by a function h, $E = h(\mu),\ h' = (-1/U'') > 0$, and the optimality conditions (5) – (9) lead to the following system of canonical equations in state (T,S) and costate (λ,μ) variables:

$$\dot{T} = A(T) - D(S) \qquad (10.1)$$

$$\dot{S} = h(\mu) - \delta S \qquad (10.2)$$

$$\dot{\lambda} = (\rho - A'(T))\lambda - V'(T) \qquad (10.3)$$

$$\dot{\mu} = (\rho + \delta) + \lambda D'(S) \qquad (10.4)$$

The Jacobian of the system $(10.1)-(10.4)$ evaluated at the equilibrium is given by the following matrix:

$$J=\begin{bmatrix}\partial\dot{T}/\partial T & \partial\dot{T}/\partial S & \partial\dot{T}/\partial\lambda & \partial\dot{T}/\partial\mu\\ \partial\dot{S}/\partial T & \partial\dot{S}/\partial S & \partial\dot{S}/\partial\lambda & \partial\dot{S}/\partial\mu\\ \partial\dot{\lambda}/\partial T & \partial\dot{\lambda}/\partial S & \partial\dot{\lambda}/\partial\lambda & \partial\dot{\lambda}/\partial\mu\\ \partial\dot{\mu}/\partial T & \partial\dot{\mu}/\partial S & \partial\dot{\mu}/\partial\lambda & \partial\dot{\mu}/\partial\mu\end{bmatrix}=$$

$$=\begin{bmatrix}A' & -D' & 0 & 0\\ 0 & -\delta & 0 & -1/U''\\ -V''-A''V'/(\rho-A') & 0 & (\rho-A') & 0\\ 0 & V'D''/(\rho-A') & D' & \rho+\delta\end{bmatrix} \tag{11}$$

The following Dockner's formula (Dockner, 1985) computes the four eigenvalues σ_i, $i=1,2,3,4$ of the Jacobian (11) which are crucial to characterize the local dynamics of the canonical system (10)

$$\sigma_{1,2,3,4}=(\rho/2)\pm\sqrt{(\rho/2)^2-(\Psi/2)\pm\tfrac{1}{2}\sqrt{\Psi^2-4\|J\|}} \tag{12}$$

coefficient Ψ is the following sum

$$\Psi=\begin{Vmatrix}\dfrac{\partial\dot{T}}{\partial T} & \dfrac{\partial\dot{T}}{\partial\lambda}\\ \dfrac{\partial\dot{\lambda}}{\partial T} & \dfrac{\partial\dot{\lambda}}{\partial\lambda}\end{Vmatrix}+\begin{Vmatrix}\dfrac{\partial\dot{S}}{\partial S} & \dfrac{\partial\dot{S}}{\partial\mu}\\ \dfrac{\partial\dot{\mu}}{\partial S} & \dfrac{\partial\dot{\mu}}{\partial\mu}\end{Vmatrix}+2\begin{Vmatrix}\dfrac{\partial\dot{T}}{\partial S} & \dfrac{\partial\dot{T}}{\partial\mu}\\ \dfrac{\partial\dot{\lambda}}{\partial S} & \dfrac{\partial\dot{\lambda}}{\partial\mu}\end{Vmatrix} \tag{13}$$

and the determinant is:

$$\det\ J=\delta A'(A'-\rho)(\delta+\rho)+\frac{A''V'D'^2}{U''(\rho-A')}+\frac{D'^2V''}{U''}+\frac{D''A'V'}{U''} \tag{14}$$

$$\Psi=A'(\rho-A')-\delta(\delta+\rho)+D''V'/(U''(\rho-A')) \tag{15}$$

Following Dockner (1985), for the saddle point stability it suffice $\|J\|>0$ and $\Psi<0$ conditions which satisfied, only if the abatement function is decreasing, i.e. $A'<0$. The above result is recorded as follows.

Proposition 2. In the pollution management model (1) – (3), the saddle point stability is ensured only in the case of decreasing abatement $A'<0$.

Proof

Follows immediately from (14) and (15) for $A'<0$ and taking the assumptions about the concavity of the utility functions.

More complex results are possible in the case of increasing abatement $A'(T)>0$. If $0<A'(\hat{T})<\rho$, then there occurs a transition from a domain of stable to locally unstable spirals and this transition give birth to limit cycles. More precise condition $A' = 0$ (or equivalently the point $\hat{T}$), separates the domain of stable policies from the domain where possible complexities arise. In fact, the supposition of growth, $A'(T) > 0$ for $T < \hat{T}$, is crucial. Supposing that abatement follows the diffusion process for the environmental state with one and only one point $\hat{T}$, such that $A'(\hat{T}) = 0$, the implication is that the time path of the environmental state consists of a convex segment (if $T < \hat{T}$) and a concave segment (if $T > \hat{T}$), with respect to time.

This in turn implies that the domain of low quality environmental state $T < \hat{T}$ exhibits increasing returns and the domain of high environmental state quality exhibits diminishing returns. While diminishing returns (i.e. a point lying inside the concave segment) it is plausible to lead to stable equilibrium, increasing returns to environmental state lead to cycles. This is because a low quality environmental state may increase to certain threshold so it may be rational for the polluters to lower production and therefore the pollutants accumulation. The following figure shows the segments for which the two different kinds of equilibrium taking place.

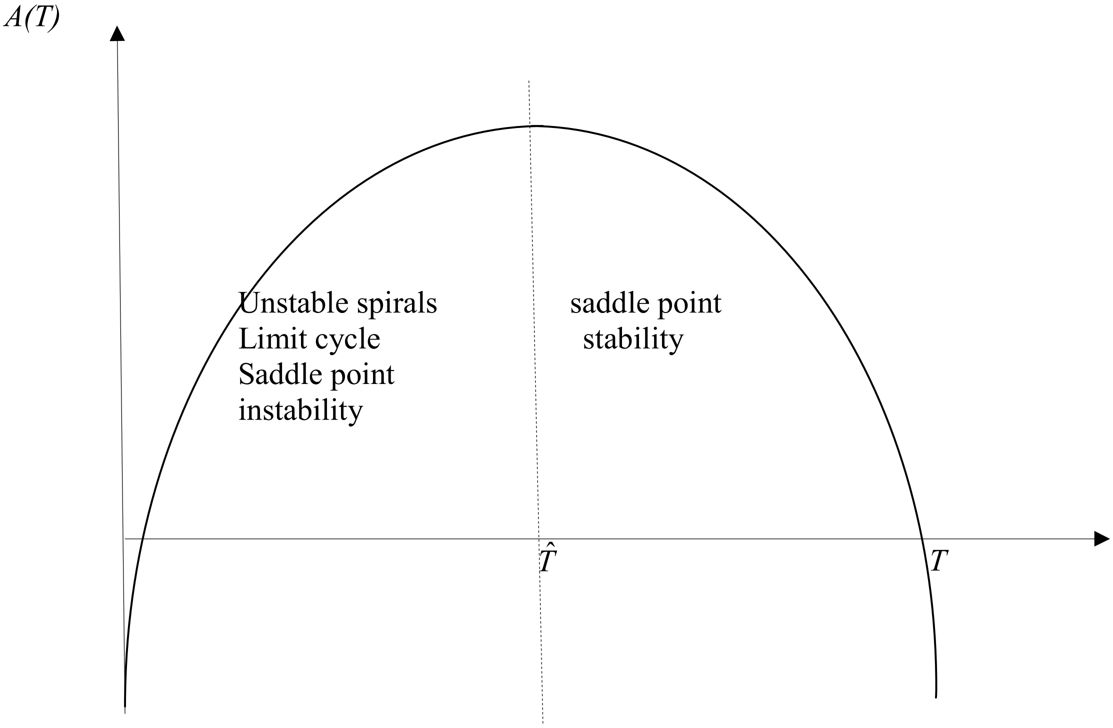

Figure 1. Properties of equilibrium depending on environmental state.

4. Exploring the limit cycle equilibrium

We specify quadratic benefits from the high environmental state, the same quadratic form for the utility arising from emissions and a linear function for the damages stemming from pollutants accumulation, i.e.:

$$U(E) = a_1 E - \tfrac{1}{2} a_2 E^2 \tag{16.1}$$

$$V(T) = \beta_1 T - \tfrac{1}{2} \beta_2 T^2 \tag{16.2}$$

$$A(T) = T(1-T) \tag{16.3}$$

$$D(S) = \gamma S \tag{16.4}$$

Equations (16.1) and (16.2) represent the fact that a high quality level of environment exists toward which T grows in the absence of pollution, while the decline in environmental quality is proportional to the accumulated level of pollutants S.

Assuming that the natural purification rate of the accumulated stock of pollutants is equal to zero, i.e., $\delta = 0$, yielding $\hat{E}^* = 0$ in the long run equilibrium. Additionally we assume $V'' = -\beta_2 = 0$ in order to ease the analysis that follows.

Thus, in determinant (14) the only term that remains is the second, and in coefficient (15) remains the second term as well. Then, the final expressions for the Jacobian and coefficient respectively, are:

$$\det J = \frac{A'' V' D'^2}{U''(\rho - A')} = \frac{2\beta_1 \gamma^2}{a_2(\rho - A')} \tag*{$(14)'$}$$

$$\Psi = A'(\rho - A') \tag*{$(15)'$}$$

For any equilibrium satisfying $0 < A'(\hat{T}) < \rho$, $(14)'$ as well as $(15)'$ is positive. According to Grass et al (2008) the condition for limit cycle equilibrium, i.e., the existence of purely imaginary roots, requires the following relation

$$\det J - \left(\frac{\Psi}{2}\right)^2 - \rho^2 \frac{\Psi}{2} = 0 \tag{17}$$

Given the parameter values as in the following table

a_1	a_2	γ	ρ	δ
1	1	0.071	1	0

and choosing the parameter β_1 as the bifurcation parameter, there exist a unique equilibrium at

$$\left(\hat{T}, \hat{S}, \hat{\lambda}, \hat{\mu}\right) = \left(\frac{7}{200}\beta_1, \frac{1}{2}\beta_1 - \frac{7}{400}\beta_1^2, \frac{100}{7}, -1\right)$$

Now relation (17) becomes the following quartic equation in β_1

$$\frac{7}{50}-\frac{7}{20}\beta_1+\frac{49}{40000}\beta_1^2+\frac{343}{2000000}\beta_1^3-\frac{2401}{400000000}\beta_1^4=0$$

for which the solution is:

$$(\beta_1)_{1,2,3,4}=6.6910;\ \ 7.5947;\ \ -15.4403;\ \ 29.7260 \qquad (18)$$

for which only the two first values for β_1 are acceptable, since β_1 is positive and $\hat{T}\in(0,1)$. Moreover, at these critical parameters both $\det J$ and Ψ are positive, i.e., one pair of purely imaginary roots exists. The final result is, for the intermediate values of the bifurcation parameter $\beta_1\in(6.6910\ ,\ 7.5947)$, the existence of complex eigenvalues all with positive real part.

Following Grass et al (2008) one can draw the limit cycle with above values of the parameter β_1. Moreover, it can be proved numerically the existence of a two dimensional stable manifold of a limit cycle and the existence of a "strong" unstable manifold explaining some inaccurate results of the IVP approach.

5. The differential game model

In the second part of the paper we make the assumption that the damage function of environmental quality is a function of the intensity of emissions and as well as a function of the intensity of the abatement process.

Let us denote by $X(t)$ the instantaneous state of environment at time t. Without any damages caused by pollution and also without any actions undertaken by the polluters the stock of environmental quality grows according to the function $G(X)$. This function is considered as growth function, obviously dependent on the state of environment, satisfying the conditions $G(0)=0$, $G(X)>0$ for all $X\in(0,K)$, $G(X)<0$ for all $X\in(K,\infty)$, $G''(X)\le 0$. Carrying out emissions is costly for the polluters, e.g. compliance costs and damages in their equipment which reduces their capital available to the production process. This clearly affects negatively the utility of the polluters. However, the reduction of the growth of the environmental quality stock, does not only depend on the intensity of emissions $u(t)$, but is also influenced by the counter pollution measures $v(t)$ undertaken by the government or by any group of agents e.g. volunteers they fight against pollution. We set as instrument variables for both sides the intensity of emissions $u(t)$ and abatement effort $v(t)$, which are assumed non-negatives $\nu(t)\ge 0,\ \ u(t)\ge 0$.

Analogously to the models of optimal harvesting natural resources one can thought the damage function as a "harvesting" the environmental resources and this harvesting is denoted by $\phi(u,\nu)$. Combining the growth $G(X)$ with the damage function $\phi(u,\nu)$ the state dynamics can be written as

$$\dot{X}=G(X)-\phi(u,\nu),\quad X(0)=X_0>0 \qquad (19)$$

Along a trajectory the non negativity constraint is imposed, i.e.

$$X(t) \geq 0 \quad \forall t \geq 0 \tag{20}$$

With the assumption of emission's compliance costs and the damages incurred in equipment due to the intensive usage, a higher intensity of emissions and also the counter pollution measures leads to stronger reduction of the polluters' resources and therefore we assume the partial derivatives of the damage function $\phi(u,\nu)$ to be positive, i.e. $\phi_u > 0,\ \phi_\nu > 0$. Moreover the law of diminishing returns is applied only for the emission realizations, that is $\phi_{uu} < 0$ and for simplicity we assume $\phi_{\nu\nu} = 0$. Additionally, we assume that the Inada conditions, which guarantee that the optimal strategies are nonnegative, holds true, i.e.

$$\begin{aligned} &\lim_{u\to 0}\phi_u(u,\nu) = \infty, \qquad \lim_{u\to\infty}\phi_u(u,\nu) = 0 \\ &\lim_{\nu\to 0}\phi_\nu(u,\nu) = 0, \qquad \lim_{\nu\to\infty}\phi_\nu(u,\nu) = \infty \end{aligned} \tag{20a}$$

The utility functions the two players want to maximize defined as follows:
Player 1, the polluter, derive instantaneous utility, on one hand from their emissions which gives rise to increasing and convex costs $C(u)$. On the other hand, a high stock of good environmental quality incur compliance costs and the induced disutility is described by the increasing function $D(X)$. With the above assumptions, player's 1 present value of utility is described by the following functional

$$J_1 = \int_0^\infty e^{-\rho_1 t}\left[\phi(u,\nu) - D(X) - C(u)\right]dt \tag{21}$$

Player 2, the benevolent social planner or any group of a high quality environmental services enjoyers, derive utility $\upsilon(X)$ from the quality of environmental state $X(t)$, but also from their abatement at intensity ν, which is described by the function $A(\nu)$. For the utilities $\upsilon(X)$ and $A(\nu)$ we assume that are monotonically increasing functions with decreasing marginal returns, i.e., $\upsilon'(X) > 0,\ A'(\nu) > 0$ and $\upsilon''(X) < 0,\ A''(\nu) < 0$. So, player's 2 utility function is defined, in its additively separable form, as:

$$J_2 = \int_0^\infty e^{-\rho_2 t}\left[\upsilon(X) + A(\nu)\right]dt \tag{22}$$

5.1 Nash Equilibrium

In this section we calculate the Nash equilibrium of the pollution differential game. The concept of open loop Nash equilibrium is based on the fact that every player's strategy is the best reply to the opponent's exogenously given strategy. Obviously, equilibrium holds if both strategies are simultaneously best replies.

Following Dockner *et al* (2000), we formulate the current value Hamiltonians for both players, as follows

$$H_1 = \phi(u,\nu) - D(X) - C(u) + \lambda\big(G(X) - \phi(u,\nu)\big)$$

$$H_2 = \upsilon(X) + A(\nu) + \mu\big(G(X) - \phi(u,\nu)\big)$$

The first order conditions, for the maximization problem, are the following system of differential equations for both players:
First, the maximized Hamiltonians are

$$\frac{\partial H_1}{\partial u} = (1-\lambda)\phi_u(u,\nu) - C'(u) = 0 \qquad (23)$$

$$\frac{\partial H_2}{\partial \nu} = A'(\nu) - \mu\phi_\nu(u,\nu) = 0 \qquad (24)$$

and second, the costate variables are defined by the equations

$$\dot{\lambda} = \rho_1\lambda - \frac{\partial H_1}{\partial X} = \lambda[\rho_1 - G'(X)] + D'(X) \qquad (25)$$

$$\dot{\mu} = \rho_2\mu - \frac{\partial H_2}{\partial X} = \mu[\rho_2 - G'(X)] - \upsilon'(X) \qquad (26)$$

The Hamiltonian of the player 1, H_1, is concave in the control u as far as long $\lambda < 1$ and is guaranteed by the assumptions on the signs of the derivatives, i.e. $\phi_{uu} < 0,\ \phi_{\nu\nu} = 0$ and from the decreasing marginal returns on the polluters' utilities, i.e. $\upsilon''(X) < 0,\ A''(\nu) < 0$. Optimality condition (23) implies that the adjoint variable λ is positive, only in the case for which the polluter's marginal utility ϕ_u exceeds the marginal costs, since (23) implies that:

$$\lambda = \left(\phi_u(u,\nu) - C'(u)\right) / \phi_u(u,\nu)\ .$$

We also assume linearity of the model. To be more precise we specify the following functions of the game to be in linear form:

i. the environmental growth function is exponential i.e.,in the form $G(X) = \omega \cdot X$, where ω is the growth rate,
ii. the polluter's disutility function, $D(X)$, stemming from the compliance costs, in the form $D(X) = D \cdot X$ and finally
iii. the polluter's cost stemming from emission's realizations in the form $C(u) = C \cdot u$

All the constants involved are positive numbers, that is $\omega, D, a > 0$. From the environmental quality enjoyers side, the functions that maximized are specified linear, i.e. the utilities arising from the high quality environmental stock and abatement are written as $\upsilon(X) = \upsilon \cdot X(t)$ and $A(\nu) = A \cdot \nu(t)$ respectively.

After the above simplified specifications the canonical system of equations (23) - (26) can be rewritten as follows:

$$\frac{\partial H_1}{\partial u} = (1-\lambda)\phi_u(u,\nu) - C = 0 \qquad (27)$$

$$\frac{\partial H_2}{\partial \nu} = A - \mu\phi_\nu(u,\nu) = 0 \qquad (28)$$

$$\dot{\lambda} = \rho_1\lambda - \frac{\partial H_1}{\partial X} = \lambda[\rho_1 - \omega] + D \qquad (29)$$

$$\dot{\mu} = \rho_2\mu - \frac{\partial H_2}{\partial X} = \mu[\rho_2 - \omega] - \upsilon$$

(30)

and the limiting transversality conditions has to hold

$$\lim_{t\to\infty} e^{-\rho_1 t} X(t)\lambda(t) = 0, \quad \lim_{t\to\infty} e^{-\rho_2 t} X(t)\mu(t) = 0 \tag{31}$$

The analytical expressions of the adjoint variables $(\lambda,\ \mu)$, solving equations (29)-(30), are respectively:

$$\lambda(t) = \frac{D}{-\rho_1 + \omega} + e^{(\rho_1 - \omega)t}\Omega_1 \tag{32}$$

$$\mu(t) = -\frac{\upsilon}{-\rho_2 + \omega} + e^{(\rho_2 - \omega)t}\Omega_2 \tag{33}$$

In order the transversality conditions to satisfied it is convenient to choose the constant steady state values, and therefore the adjoint variables collapses to the following constants

$$\lambda = \frac{-D}{\rho_1 - \omega}, \quad \mu = \frac{\upsilon}{\rho_2 - \omega} \tag{34}$$

To ensure certain signs for the adjoints (34) we impose another condition on the discount rates, which claim that discount rates are greater than the resource's growth, i.e. we impose the condition

$$\rho_i > \omega, \quad i = 1,2$$

thus, the constant adjoint variables has the negative and positive signs respectively,i.e,

$$\lambda = \frac{-D}{\rho_1 - \omega} < 0, \quad \mu = \frac{\upsilon}{\rho_2 - \omega} > 0$$

The above condition seems to be restrictive but can be justified as otherwise optimal solutions do not exist. Indeed, choosing $\rho_2 < \omega$, the government's discount rate to be lower than the environmental growth rate, their objective functional becomes unbounded in the case they choose to send out no emissions. Similarly, choosing the government's discount rate lower than the growth rate the associated adjoint variable λ becomes a positive quantity in the long run. As a shadow price is implausible to be positive for optimal solutions, the above reasoning is sufficient for the assumption $\rho_i > \omega,\ i = 1,2$.

Once the concavity of the Hamiltonians, with respect to the strategies, for both players is satisfied the first order conditions guarantee its maximization. Now, we choose the function's $\phi(u,\nu)$ specification, i.e. the specification of the damage function. This function is depending on the intensity of emissions and also depending on the abatement actions undertaken by the social planner. We choose a similar to Cobb – Douglas production function specification, which characterized by constant elasticities, and is in the following form

$$\phi(u,\nu) = u^{\sigma}\nu^{\zeta} \qquad 0 < \sigma < 1 < \zeta$$

The rest of the paper is devoted to the calculations of the explicit formulas at the Nash equilibrium.

5.2. Optimal Nash Strategies

Applying first order conditions for the chosen specification function

$$\phi_u(u,\nu)=\frac{C}{1-\lambda} \quad \Leftrightarrow \quad \sigma u^{\sigma-1}\nu^{\zeta}=\frac{C}{1-\lambda} \tag{35}$$

$$\phi_\nu(u,\nu)=\frac{A}{\mu} \quad \Leftrightarrow \quad \zeta u^{\sigma}\nu^{\zeta-1}=\frac{A}{\mu} \tag{36}$$

The combination of (35) and (36), using the Cobb–Douglas type of specification, reveals an existing interrelationship between the strategies, i.e.

$$\phi\left(u^*,\nu^*\right)=\left(u^*\right)^{\sigma}\left(\nu^*\right)^{\zeta} \quad \Leftrightarrow \quad \frac{Cu^*}{\sigma(1-\lambda)}=\frac{A\nu^*}{\zeta\mu} \quad \Leftrightarrow \quad \nu^*=u^*\frac{C\zeta\mu}{\sigma(1-\lambda)A} \tag{37}$$

Expression (37) now predicts the interrelationship between the player's Nash strategies, for which the result of comparison between them is dependent on the constant parameters and on the constant adjoint variables, as well.

Substituting back (37) into (36) we are able to find the analytical expressions of the strategies, after the following algebraic calculations. Expression (36) now becomes:

$$\left(u^*\right)^{\sigma+\zeta-1}=\left[\frac{C}{\sigma(1-\lambda)}\right]^{1-\zeta}\left(\frac{\zeta\mu}{A}\right)^{1-\zeta}\left(\frac{\mu\zeta}{A}\right)^{-1}=\left[\frac{C}{\sigma(1-\lambda)}\right]^{1-\zeta}\left(\frac{\mu\zeta}{A}\right)^{-\zeta}$$

and from the latter the analytical expressions for the equilibrium strategies is derived in a more comparable form now:

$$u^*=\left[\frac{C}{\sigma(1-\lambda)}\right]^{\frac{1-\zeta}{\sigma+\zeta-1}}\left(\frac{\mu\zeta}{A}\right)^{\frac{-\zeta}{\sigma+\zeta-1}} \tag{38}$$

$$\nu^*=\left[\frac{C}{\sigma(1-\lambda)}\right]^{\frac{\sigma}{\sigma+\zeta-1}}\left(\frac{\zeta\mu}{A}\right)^{\frac{\sigma-1}{\sigma+\zeta-1}} \tag{39}$$

Further substitutions in the equation of the resources accumulation, $\dot{X}=\omega X-u^{\sigma}\nu^{\zeta}$, yield the following steady state value of the environmental quality stock

$$X^{ss}=\frac{1}{\omega}\left[\frac{C}{(1-\lambda)\sigma}\right]^{\frac{\sigma}{\sigma+\zeta-1}}\left(\frac{\zeta\mu}{A}\right)^{\frac{-\zeta}{\sigma+\zeta-1}} \tag{40}$$

We summarize the above discussion in a proposition.

Proposition 3:

Assuming the function which damages the environmental quality to exhibit constant elasticity and all the other functions to be linear, then the pollution game yields constant optimal Nash strategies. The analytical expressions of the strategies are given by (38) and (39) for the government and the polluters respectively. The steady state value of the resources' stock is given by the expression (40).

5.3. The Value Functions

In this section we compute the analytical expressions for the values of objective functions of the players. For this purpose we make use the constancy of the strategies (38), (39) computed above. We denote the pair of the constant strategies as $(\bar{u},\bar{\nu})$. Note

that constant strategies, leads to a constant function $\bar{\phi}=\phi(\bar{u},\bar{\nu})$ which is the aforementioned damage function that reduces the environmental quality. The equation of the environmental quality state, now can be solved explicitly with the following analytical solution

$$X(t)=\left(X_0-\frac{\bar{\phi}}{\omega}\right)e^{\omega t}+\frac{\bar{\phi}}{\omega} \tag{41}$$

X_0 is the initial stock of the environmental quality. Note that expression (41) leads us to assume a sufficiently high initial stock of resources, specifically $X_0 \geq \bar{\phi}/\omega$, in order to satisfy the non-negativity condition $X(t)>0$.

The earlier computed constant strategies and the linearity assumption of the value functionals for both government and polluters, gives us the advantage to calculate a linear integral. Thus, for the value function of player 1, we have:

$$J_1=\frac{1}{\rho_1}\left(\bar{\phi}-C\cdot\bar{u}\right)-D\int_0^{\infty}e^{-\rho_1 t}X(t)\,dt \tag{42}$$

The value of the integral in (42) can be computed, giving $\int_0^{\infty}e^{-\rho_1 t}X(t)\,dt=\dfrac{\rho_1 X_0-\bar{\phi}}{\rho_1(\rho_1-\omega)}$

The polluters' value function (42) now takes the following form:

$$J_1=\frac{\bar{\phi}}{\rho_1}\left(1+\frac{D}{\rho_1-\omega}\right)-\frac{C\bar{u}}{\rho_1}-\frac{DX_0}{\rho_1-\omega} \tag{43}$$

which is again a constant.

Similarly, thanks to the model's linearity, the government's value function can be calculated analytically yielding the following constant expression:

$$J_2=\frac{1}{\rho_2}\left(A\bar{\nu}+\frac{\upsilon\left(\rho_2X_0-\bar{\phi}\right)}{\rho_2-\omega}\right)=-\frac{\upsilon\bar{\phi}}{\rho_2\left(\rho_2-\omega\right)}+\frac{A\bar{\nu}}{\rho_2}+\frac{\upsilon X_0}{\rho_2-\omega} \tag{44}$$

6. Conclusions

The purpose of this paper was to investigate the dynamics of pollution together with the actions undertaken for counter pollution. For this purpose we setup firstly a model of environmental pollution management and secondly a game between the polluters and the enjoyers of environmental services. For the first model of high quality environmental services management we make as basic assumption, that the environment may serve as an input to the production of conventional goods and also the environment itself may provide services enjoyed by the people. In the management model setup the state variables are the environmental quality and the stock of pollutants, as well. In the analysis of the solution we explore not only the restricted case of the saddle point equilibrium, but we enrich the equilibrium space with the wider class of the limit cycles, applying the Hopf's bifurcation theorem. We found, in the case of the saddle point the necessary condition is the decreasing abatement, while in the case of increasing abatement the result is the richer limit cycle equilibrium. Moreover, following numerical analysis, we found numerically the region for which the two dimensional stable manifold of the limit cycle exists.

In the second model, the crucial assumption made is not the traditional one in which the environment is damaged only from the pollutants accumulation. Instead, we claim the function which damages the environmental services is not only affected positively by the pollutants accumulation but is affected negatively by the abatement effort undertaken by the second group of players. The two players, involved in the differential game, maximize their own utilities subject to a common equation of motion of the environmental state. Player 1 is the group of polluters which damage the environmental quality emitting pollutants at an instant intensity $u(t)$, but they suffer from the compliance costs as from the costs of emission realizations. Player 2 is every group of pollutants wipers which they derive utility form the clean environment but also utility from their abatement effort $A(\nu(t))$. Considering the environment's equation of motion we assume that the environmental quality grows at an exponential rate and also we assume the damage function is in the form of a Cobb–Douglas with constant elasticities. Finally, in the game, we set as instrument variables the intensity of emissions on behalf the player 1 and the abatement effort on behalf the group that abates.

The game analysed here has the important property of the state separability. Like linear quadratic games state separable differential games exhibit a special structure which allows an analytical characterization of Nash solutions. Moreover, state separable games have the important property that the Nash equilibrium is Markov perfect solutions.

In the solution process and under some simplifications we found the analytical expressions of the induced strategies for both players. The equilibrium analysis reveals an important interrelationship between the strategies which are presented here in a comparable form. Finally, for the game model we found the value functions for both players which are, as the strategies, dependent only on the model parameters, hence time consistent.

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Regulating climate change using geoengineering methods when countries are heterogeneous[38]

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Abstract
We study a simple dynamic game of optimal policy design in terms of emissions and geoengineering efforts involving two heterogeneous countries. We seek to characterize cooperative and non-cooperative emission strategies in the framework of asymmetric countries. On the modeling side we consider a world consisting of two asymmetric countries with production activities that generate GHG emissions. We formulate the heterogeneity between the two countries in terms of the social cost of geoengineering, the environmental changes due to climate change, the productivity of the country, the cost of emissions due to the production of the country, the time preference, the private cost of geoengineering and the combination of productivity of the country and the social cost of geoengineering. We are interested in analyzing the impact of each instrument alone to each country's decision about her own emissions and geoengineering level.

Keywords: Climate change, heterogeneity, geoengineering, cooperation, differential game, feedback Nash equilibrium, asymmetry

JEL: Q53, Q54.

1 Introduction

Human-driven climate change due to greenhouse gas emissions is becoming increasingly important as a driver of biodiversity loss and the degradation of ecosystem services. Even under the most optimistic scenarios, greenhouse gas concentrations are predicted to continue to rise into the future leading to significant global warming. The only sustainable solution to human-induced climate change is the reduction in anthropogenic greenhouse gas creation and release. Given the scale of the task and the current institutional lock-in of fossil fuel energy, there has been minimal political progress made toward this solution over the last 30 years.

On the basis of current greenhouse gas emissions, their long atmospheric residence times and the relatively limited action to date to reduce future emissions, the use of geoengineering techniques has also been suggested as an additional means to limit the

[38] This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program «Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: Thalis – Athens University of Economics and Business - "Optimal Management of Dynamical Systems of the Economy and the Environment.

magnitude of human-induced climate change and its impacts. Geoengineering is defined as a deliberate intervention in the planetary environment of a nature and scale intended to counteract anthropogenic climate change and its impacts. Geoengineering techniques include increasing the reflectivity of the Earth's surface or atmosphere, and removing greenhouse gases from the atmosphere; other approaches have also been proposed. Geoengineering can be differentiated from actions that mitigate (reduce or prevent) anthropogenic greenhouse gas emissions. **Sunlight reflection methods (SRM)**, also known as solar radiation management, aim to counteract warming and associated climatic changes by reducing the incidence and subsequent absorption of short-wave solar radiation, reflecting a small proportion of it back into space. They are expected to rapidly have an effect once deployed at the appropriate scale, and thus have the potential to reduce surface global temperatures within a few months or years if that were considered desirable.

In this paper we examine a specific geoengineering proposal that suggests pumping sulphur dioxide into the stratosphere to shade the earth from the sun by spreading very small reflective particles. This mimics what occasionally occurs in nature when a powerful volcano erupts. For example, the Mount Pinatubo eruption in 1991 injected huge volumes of sulphur into the stratosphere. The particles produced in subsequent reactions cooled the planet by about 0.5^o C over the next two years by reflecting sunlight back out to space.

The definition of geoengineering encompasses a wide spectrum of possible actions to counteract (or remedy) global warming and its associated consequences. The commonality of those actions is that they could produce global cooling, if applied at sufficient scale. The deployment of geoengineering techniques, if feasible and effective, could reduce the magnitude of climate change and its impacts on biodiversity. At the same time, most geoengineering techniques are likely to have unintended impacts on biodiversity, particularly when deployed at a climatically-significant scale, together with significant risks and uncertainties. Furthermore, while approaches using SRM have the potential to offset the radiative effects of all greenhouse gases, they do not directly alleviate other consequences of changes in atmospheric chemistry, such as ocean acidification. SRM is expected to rapidly have an effect on climate if deployed at the appropriate scale.

However, SRM does not treat the root cause of anthropogenic climate change, arising from increasing greenhouse gas concentrations in the atmosphere, nor would it directly address ocean acidification or the CO2 fertilization effect. Moreover, it would introduce a new dynamic between the warming effects of greenhouse gases and the cooling effects of SRM with un- certain climatic implications, especially at the regional scale. Another issue surrounding geoengineering is that of "moral hazard", the possibility that if large-scale climate engineering is indeed deployed to counteract increases in global temperature, then nothing significant will be done to reduce greenhouse gas emissions as global warming will no longer be perceived as a problem. If this were to happen then geoengineering efforts would need to be maintained for many years to keep global warming below potentially dangerous levels. The expectation that humankind would be able to continuously maintain a geoengineering effort at the required level for this length of time is questionable.

According to a previous paper from Manousi, Xepapadeas the presence of geoengineering as a policy option results a higher level of steady state accumulation of GHGs relative to the case where geoengineering is not an option. This result holds at the cooperative and noncooperative solutions, with relatively stronger incentives for geoengineering at the noncooperative solutions. Higher GHGs could be compatible with lower global temperature, at least in the short run, since geoengineering increases global albedo which tends to reduce temperature. Thus geoengineering could lead to a solution of relatively higher GHGs and temperature, or relatively higher GHGs but lower temperature relative to the case where geoengineering is not an option. The outcome is largely an empirical issue with many deep structural uncertainties. Another result stemming from the aforementioned analysis is that even if geoengineering leads to a lower temperature, maintaining this temperature requires a constant row of geoengineering. Thus, if this row cannot be kept constant at some point in time, then there will be a jump in the temperature which will be intensified since the stock of GHGs will already be high.

In this paper, we study a simple dynamic game of optimal policy design in terms of emissions and geoengineering efforts involving two heterogeneous countries. The model we develop consists of a traditional economic module along with a climate module based on a simplified energy balance climate model (EBCM). EBCMs are based on the idea of global radiative heat balance. In radiative equilibrium the rate at which solar radiation is absorbed matches the rate at which infrared radiation is emitted. The purpose of geoengineering as a policy instrument is to reduce global average temperature by controlling the incoming solar radiation.

We seek to characterize cooperative and noncooperative emission strategies in the framework of asymmetric countries. On the modeling side we consider a world consisting of two asymmetric countries with production activities that generate GHG emissions. The stock of GHGs blocks outgoing radiation and causes temperature to increase. Geoengineering blocks incoming radiation which is expected to cause a drop in temperature. This drop does not, at least in the way that our model is developed, depend on the accumulated GHGs.

We analyze the problem, as it is usual in this type of problems, in the context of cooperative and noncooperative solutions. In the cooperative case there is coordination between the two countries for the implementation of geoengineering and the level of emissions in order to maximize the joint, or global, welfare. In the noncooperative case, each government chooses geoengineering and emissions policies noncooperatively, in this case we analyze feedback Nash equilibrium (FBNE) strategy. We first derive the optimal steady state level of geoengineering, emissions, temperature and GHGs accumulation under the fully symmetric scenario, in cooperation and feedback Nash strategies, and compute the associated welfare level of each country. Although this scenario is unlikely to occur in practice it does serve as a useful benchmark against which other outcomes may be compared.

We formulate the heterogeneity between the two countries in terms of the social cost of geoengineering, the environmental changes due to climate change, the productivity of the country, the cost of emissions due to the production of the country, the time preference, the private cost of geoengineering and the combination of productivity of the country and the social cost of geoengineering. We are interested in analyzing the impact of each instrument alone to each country's decision about her own emissions and geoengineering level. We also want to study the impact of this decision to the environment in terms of the steady state stock of GHGs and the temperature.

Our first main result follows from introducing asymmetry to the social cost of geoengineering of each country. High level of social cost of geoengineering implies low level of geoengineering effort and high temperature. If the source of asymmetry between the two countries is the different productivity level that generates emissions, then we observe that the country with the relatively high productivity level will adopt a policy of high level of emissions and geoengineering and this will result high steady state stock of GHGs and temperature. On the other hand, we have the exact opposite results in steady state level of emissions, geoengineering, stock of GHGs and temperature if the source of asymmetry between the two countries is the different cost of emissions due to country's production.

Another interesting rending suggests that when environmental changes to a country due to climate change are more severe compare to the other country, then we expect that the first country will rise her geoengineering efforts and reduce her emissions. This will lead to a lower level of stock of GHGs and temperature compare to the steady state levels under symmetry. If we have a combination of high productivity level that generates emissions at the first country and a low social cost of geoengineering at the second, we observe higher emissions at the first country and higher geoengineering efforts on both countries relative to the steady state levels under symmetry. We also have higher level of stock of GHGs and temperature compare to the steady state levels under symmetry.

The last key finding concerns the difference in time preference between the two countries. If one of the countries is very impatient and the other is relatively patient then we have high level of geoengineering efforts, high emissions for the impatient and low emissions for the patient and this leads to a higher level of stock of GHGs and temperature compare to the steady state levels under symmetry.

Some graphical findings

Figure 1 presents the time path for the optimal emissions, Figure 2 presents geoengineering, Figure 3 presents the GHGs stock and Figure 4 presents the level of temperature in case of cooperation and symmetry between countries in cooperation. Similarly, Figure 5 presents the time path for the optimal emissions, Figure 6 presents geoengineering, Figure 7 presents the GHGs stock and Figure 8 presents the level of temperature in case of noncooperation and symmetry between countries in the nonCooperative solution – feedback Nash.

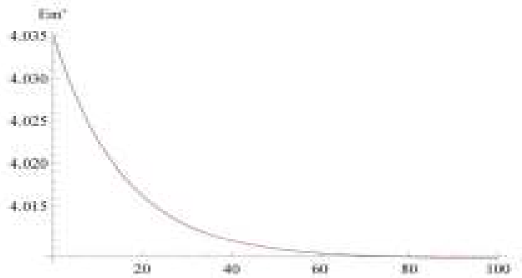


Figure 1

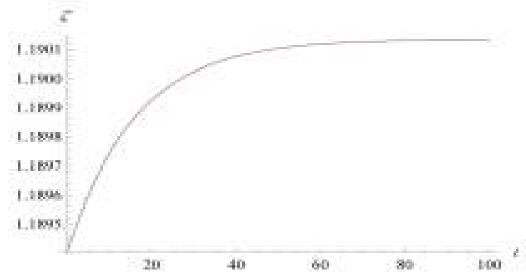
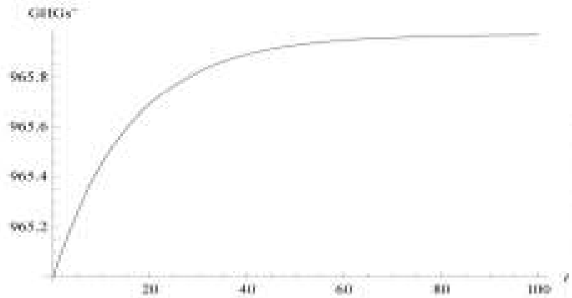


Figure 2



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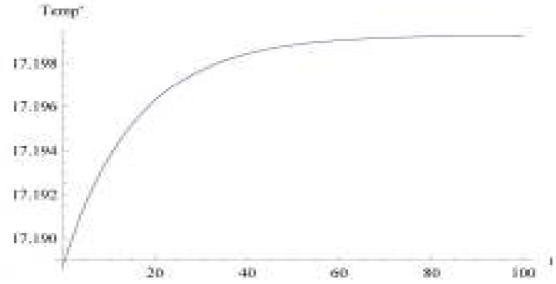

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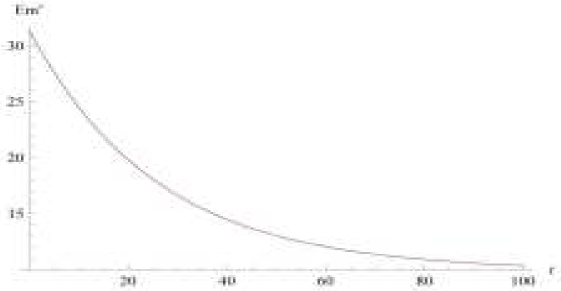

Figure 5

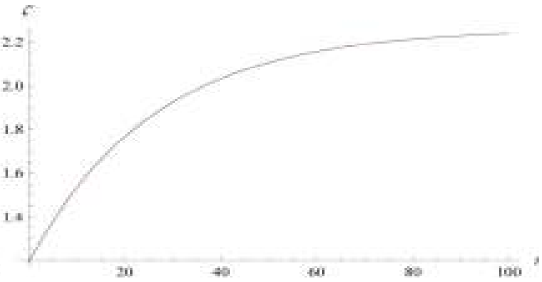

Figure 6

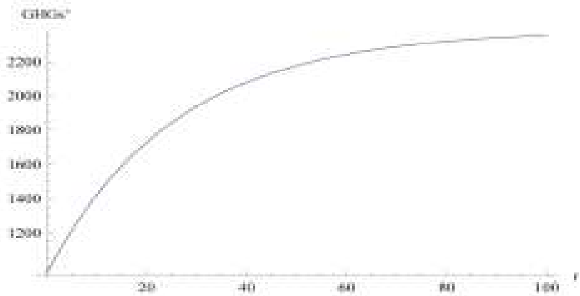

Figure 7

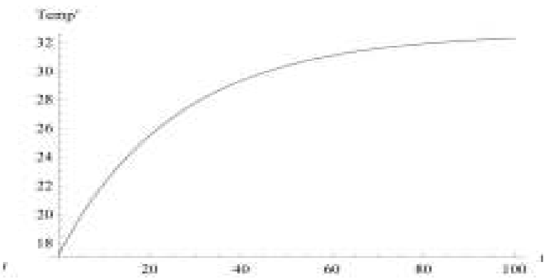

Figure 8

Conclusions

The present paper analyzed a dynamic game that was interpreted as a model of international pollution control. The theoretical results are consequently applied to a linear-quadratic model of climate change. In our simulations we solved the model under a fully cooperative and symmetric framework and we calibrated the parameters of asymmetry. The methods we employ build on the preceding theoretical analysis and may be of independent interest for robust control applications. Allowing asymmetry on several parameters of our model we observed the optimal policy of each country.

The first key finding concerns the difference in the marginal damage cost from an increase in temperature and in the marginal cost from emissions in each country. These sources of asymmetry have the same results regarding the level of emissions, temperature and stock of GHGs. In brief, if the reduction in the marginal damage cost from an increase in temperature or in emissions in one country dominates the rise of the same parameters in the other country, then emissions, temperature and stock of GHGs increase. The result is different only for the case of geoengineering. For the reduction of marginal damage cost from an increase in temperature from its steady state value we observe a reduction of geoengineering, contrariwise in the case of reduction of the marginal cost from emissions we see an increase.

Another important result caused by the asymmetry in the social cost of geo- engineering between the two countries. The country with the higher social cost of geoengineering reduces geoengineering efforts and this implies a rise in temperature. The deviation of the parameter of the level of productivity of each country gives us also important results. At first we examined the impact of the marginal benefits from production alone and we confirmed that an increase of the marginal benefits from production from its steady state value leads to an increase of emissions, geoengineering, temperature and stock of GHGs. After that we assumed a combination of an increase of the marginal benefits from production in one country along with a reduction in the social cost of geoengineering in the other. As we expected this combination of asymmetry leads to a rise of emissions, geoengineering, temperature and stock of GHGs, as the in- crease of the marginal benefits from production seems to affect more the level of temperature than the reduction in the social cost of geoengineering.

For our last finding we assumed that the source of asymmetry is the difference in discount rate between the two countries. The most interesting result follows out when we have a relatively patient and a rather impatient country. In this case the very impatient country rushing to increase her emissions along with her geoengineering efforts. Due to the increase of emissions the relatively patient country forced to increase her geoengineering efforts too, although she already has reduced her emissions. This increase of emissions from the impatient country affects the level of GHGs and temperature, which rise.

As last source of asymmetry we examined the impact of the private cost of geoengineering to our model. The results showed that the level of the private cost of geoengineering has a minor influence to the levels of emissions, geoengineering, temperature and stock of GHGs6. In specific, the deviations from the steady state level were almost zero for all of the variables, despite of the proportion of the reduction or increase of the parameter. This work suggests several interesting avenues for future research. A more complete treatment of the issues presented here would extend the basic model to incorporate the impact of geoengineering as an alternative policy option against climate change. Introduction of uncertainty - especially as deep structural uncertainty - including characteristics such as model uncertainty, ambiguity aversion, robust control methods, or regime shifts, is a very important area of further research.

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Managing Local Commons: Combining Fairness and Stability for the Management of East Atlantic and Mediterranean Tuna

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Abstract
The paper examines the issue of allocating fishing rights for the management of East Atlantic and Mediterranean tuna. Although, it is well known that fairness plays a crucial for the acceptability of international environmental agreements, usually there is a tradeoff between fairness and stability in such agreements. Our approach comprises three stages. First, various equitable rationing methods (originated from the "bankruptcy" literature) are used to allocate the fishing rights. Second, fairness and stability criteria are used to assess how appropriate these allocation rules are. The final choice was facilitated by using the index of social envy. The results highlight the likely trade-off between fairness and stability that prevails over international agreements and present a way to reconcile it.

Keywords: TAC, Common Property Resources, Bankruptcy Rules, Stability, Fairness.

1. Introduction

The management of the stock of the blue fin tuna is under the aegis of the International Commission for the Conservation of Atlantic Tunas (ICCAT). ICCAT manages the population of bluefin tuna as two separated stocks, the western Atlantic stock (BFTWA) and the Eastern Atlantic and Mediterranean stock (BFTEAM). In 1996 ICCAT responded to the peril of tuna stock over-exploitation by launching Total Allowable Catches (TAC) (Fromentin and Ravier 2005). The initial set of TAC was based on the historical catches, a rationale commonly referred to as "relative stability" (Khalilian et al. 2010). ICCAT has incorporated a number of additional considerations in allocating the TAC among countries such as the spatial distribution of stock, the proximity to coastal states and legitimate claims of countries with historically low catches (Sumaila and Huang 2012).

Distributional issues, such as allocation rules and justice claims, are always at the core of fisheries and coastal governance (Jentoft and Chuenpagdee 2009). Johansson-Stenman and Konow (2010) argues that cooperation is enhanced if the principle of efficiency is reconciled with inequality aversion. Baland (2006) found that the inequality level in the fish shares may influence the adoption of conservation measures among fishermen.

Despite the fact that there is no general accepted compliance theory for International Environmental Agreements (IEAs), fairness, according to Grossen (2004), provides the conceptual tool to manage the tension between change and order in such agreements (Mitchell 2003). However, it is not only fairness considerations which enhance cooperation, but also stability plays an important role. An agreement is taken to be stable if none of the signatories wishes to withdraw and none of the non-signatories has an incentive to join the scheme (Diamantoudi and Sartzetakis 2006).

The aim of this paper is to propose an approach that combines fairness and stability considerations in the selection of the appropriate allocation rule for the BFTEAM. The next section describes the proposed approach, section 3 presents and discusses the results, and finally the conclusions are given in section 4.

2. A novel approach for allocating the tuna TAC for the East Atlantic and Meditteranean.

Our approach comprises three steps. The first one examines various allocation rules originated from the "bankruptcy" literature as likely alternatives to the ICCAT's rationale. In the second step we apply the fairness and stability criteria to generate two sets of qualified alternatives. At last, in the third step we apply the index of social envy to get the final choice. The following figure presents the proposed approach.

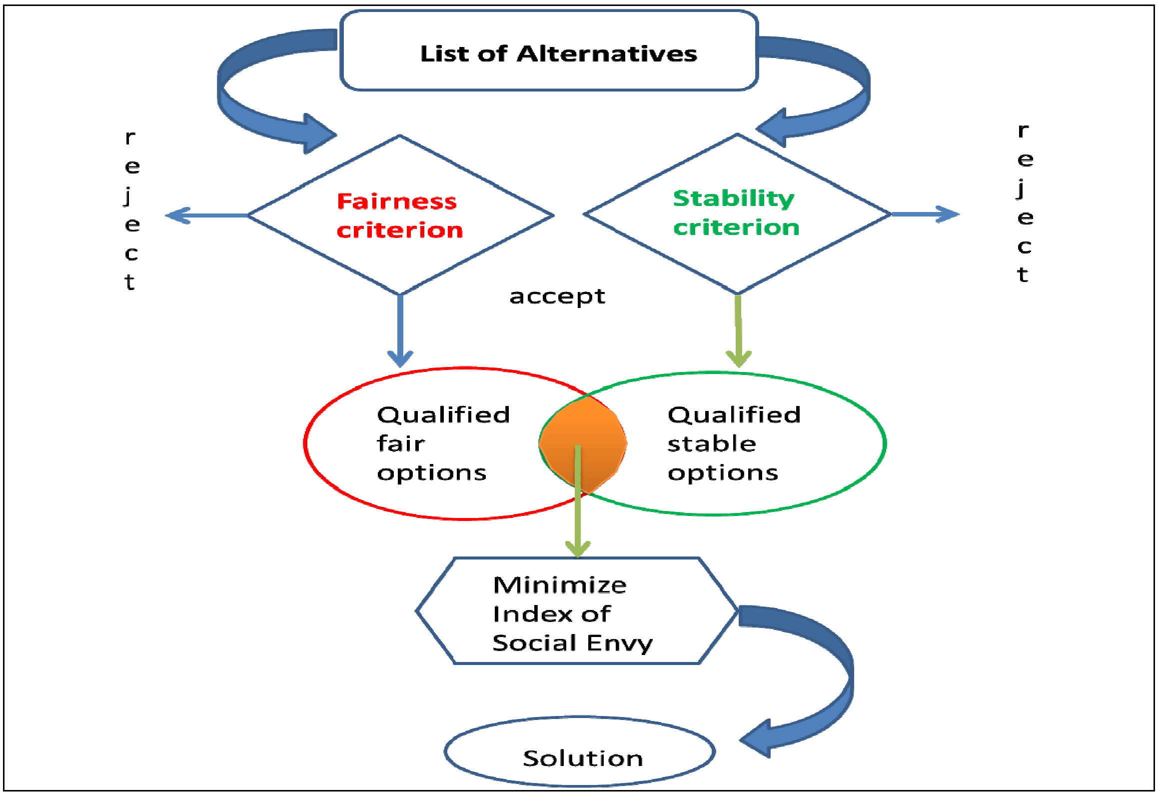

Figure 1: A novel approach to allocate TAC

2.1 Step 1: Possible Rationing Rules of allocating the Tuna TAC.

It is convenient to consider the unregulated fish catches as the vector of their claims, c, where $c \in \mathbb{R}^n_+$ and the *ith* component of c, denoted by c_i, represents the unrestricted fish catch by country i, in the baseline year, namely 2010. Hence, $\sum_{i \in N} c_i$

denotes the total unregulated fish catch or the total claims from all fishing countries. Consequently, the total allowable catches are $TAC = \sum_{i \in N} r_i = (1-a)\sum_{i \in N} c_i$, while $a\sum_{i \in N} c_i$ denotes the total required reduction in the fishing quantities of the baseline year and r_i stands for the regulated catch of the ith country.

The rationing of TAC to the involved countries is arguably the most crucial issue in designing a (voluntary) fishing management. The reason is that such an agreement is more likely to be acceptable if the involved agents perceive it as fair (Wood 2011). To this end, the paper examines a set of "equitable" allocation rules drawing from the relevant "bankruptcy" literature (Hougaard 2009). According to Brams and Taylor (1996) an "equitable" allocation rule does not necessarily assign equal shares to the involved agents but shares in proportion to their entitlements (needs, demands or claims).

The first allocation rule examined is the Equal Proportional Rule (PR), which is probably the best known method, in which proportionality is often taken as the definition of fairness for claims problems (Thomson 2003). The PR is defined as:

$$r_i = (1-a)c_i = \left(c_i \Big/ \sum_{i \in N} c_i \right)(1-a)\sum_{i \in N} c_i \qquad (1)$$

From the "bankruptcy" literature we consider the following rules. The first rule is the Constrained Equal Award (CEA). The CEA is defined as:

$$r_i = \min\left(c_i, \omega\right) \qquad (2)$$

where $\omega = (1-a)\sum_{i \in N} c_i \Big/ N > 0$. The rationale of CEA is that every country receives the same amount as long as this amount does not exceed the country's claim. Formally, if $c_i > (1-a)\sum_{i \in N} c_i \Big/ N$, then each and every country receives the same amount equal to $(1-a)\sum_{i \in N} c_i \Big/ N$. On the contrary, if $c_i < (1-a)\sum_{i \in N} c_i \Big/ n$ then the ith country receives the amount c_i and the remaining countries receive $r_j = (1-a)\sum_{j \in N-\{i\}} c_j \Big/ \left(N-1\right)$, where $\sum_{j \in N-\{i\}} c_j + c_i = \sum_{i \in N} c_i$ and $\sum_{j \in N-\{i\}} r_j + c_i = \sum_{i \in N} r_i$. Inarra and Skonhoft (2008) examined such a rule for distributing TAC concerning the North East Atlantic Norwegian cod. The CEA is the unique Lorenz-maximising rationing rule, in the sense that no other rule results in more equally distributed shares (Hougaard 2009).

Another similar rule is the Constrained Equal Loss (CEL). The CEL is defined as:

$$r_i = \max\left\{0, \psi_i\right\} \qquad (3)$$

where $\psi_i = c_i - a\sum_{i \in N} c_i \Big/ N > 0$. The rationale of the CEL is that every country receives its claim, c_i, and the required reduction is allocated equally to all countries. Formally, if

$c_i > a\sum_{i\in N} c_i \Big/ N$, then each and every country receives the amount equal $r_i = c_i - a\sum_{i\in N} c_i \Big/ N$. On the contrary, if $c_i < a\sum_{i\in N} c_i \Big/ N$ then the *ith* country receives zero amount, $r_i = 0$, and the remaining countries receive $r_j = c_j - \left(a\sum_{i\in N} c_i - c_i\right)\Big/\left(N-1\right)$, where $j \in N - \{i\}$. The CEL is the unique Lorenz-minimising rationing rule, in the sense that no other rule results in less equally distributed shares (Hougaard 2009).

Also a well-known rule is the Talmud (TALM). The TALM is defined as:

$$r_i = c_i/2 + CEL\left(c_i/2, (1-a)\sum_{i\in N} c_i - \sum_{i\in N} c_i \Big/ 2\right) \tag{4}$$

The rationale of the Talmud rule is that each country gets half of her claim and the remainder is distributed by applying the constrained equal losses rule to the vector of half claims (Bosmans and Lauwers 2011).

Another "bankruptcy" rule is the Adjusted Proportional (AP). The AP is defined as:

$$r_i = m_i + \left[\left(1-a\right)\sum_{i\in N} c_i - \sum_{i\in N} m_i\right]\rho_i \tag{5}$$

The AP rule first gives each country her minimal right, m_i, and then allocates the remainder according to the countries' new claims, ρ_i. The minimal right of country i is defined as the maximum of zero and the difference between the amount to divide and the claims of the other countries, that is $m_i = \max\left\{0, \left(1-a\right)\sum_{i\in N} c_i - \sum_{j\in N-\{i\}} c_j\right\}$, and the new claim of country i is $\rho_i = \left(c_i - m_i\right)\Big/\sum_{i\in N}\left(c_i - m_i\right)$. The rule was initially proposed and characterised by Curiel *et al.* (Curiel et al. 1987).

A modification of the AP rule is possible by adjusting the concept of minimal right. Drawing on the rationale of the constrained egalitarian rule (Bosmans and Lauwers 2011), we adjust the AP rule and coin the term Adjusted Proportion-Constrained Egalitarrin (AP-CE). In this context, we propose the following definition of the minimal right of the i country :

$$m_i = \max\left\{c_i/2, \min\left(c_i, \sum_{i\in N} c_i \Big/ N\right)\right\} \tag{6}$$

Otherwise the AP-CE works as the AP rule.

Finally, in line with Weikard et al. (2006) we examine a convex combination of the Equal and the Proportional sharing rules (E&P). Such a method allocates a proportion θ of TAC equally and the rest $\left(1-\theta\right)$ according to the equal-proportional rule. The E&P is defined as:

$$r_i = (1-\theta)(1-a)\sum_{i\in N} c_i \Big/ N + \theta\left(c_i \Big/ \sum_{i\in N} c_i\right)(1-a)\sum_{i\in N} c_i \qquad (7)$$

Giménez-Gómez and Peris (2014) defined the scalar θ as:

$$\theta = \max\left\{0, \left[\sum_{i\in N} c_i\left((1-a)\sum_{i\in N} c_i - Nc_1\right) \Big/ (1-a)\sum_{i\in N} c_i\left(\sum_{i\in N} c_i - Nc_1\right)\right]\right\} \qquad (8)$$

where c_1 is lowest claim of all countries. The resulting allocation rule by plugging (8) into (7) is termed by the authors as $a_{\min}$ Egalitarian rule (a-min) in the sense that a minimum amount $\tilde{c} > c_1$ must be received by each country. Note that this minimum amount is context specific.

2.2 Step 3: Fairness and Stability Criteria.

The reduction of inequality (or inequity aversion) is often considered to be as synonymous with the concept of distributive justice (Konow 2001), whereas the latter is a manifestation of fairness (Konow 1996). To this end, we assess the likely fairness of the alternative allocation rules by using inequality indices. Among various such indices we restrict our attention to the Atkinson Index (A), the Gini coefficient (G) and the Generalized Entropy one (GE). The Atkinson Index, A, is given by:

$$A = 1 - \left(\frac{1}{N}\sum_i \left(r_i \big/ \mu\right)^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}} \qquad \varepsilon \neq 1 \qquad (9)$$

where, r_i stands for the fish quotas of the *ith* country and μ is the average fish quotas. The parameter $\varepsilon > 0$ represents the weight attached by ICCAT to inequality in fish quotas. The higher the parameter ε is the higher the sensitivity attached to the transfers to the countries with small fish quotas. The index A ranges from zero to $(1-n)^{-\frac{\varepsilon}{1-\varepsilon}}$. According to Barr (1998), the A can be seen as an index of the potential gains from redistribution. The index A explicitly introduces such judgements through the choice of the parameter ε , which ranges from $\varepsilon = 0$ meaning that society is indifferent about income distribution, to $\varepsilon = \infty$, which means that society is concerned only with the position of the least advantaged members of society. The latter case corresponds to what Rawls (1971) refers to as a contractual theory of justice, where inequality is assessed in terms of the position of the last advantaged members of society. Despite the numerous advantages of the A index (see Temkin (1993) pp:137-138) the main problem attached to it is that there is no way of fully calibrating ε .

The Gini Index is arguably the most-known inequality index (Temkin 1993), which is given by:

$$G = \frac{1}{2N^2\mu}\sum_i \sum_j \left|r_i - r_j\right| \qquad (10)$$

Values close to zero indicate minimal inequality whereas values close to 1 (or 100%) reflect maximal inequality.Finally, the Generalised Entropy is given by

$$GE(a) = \frac{1}{a^2 - a}\left[\frac{1}{N}\sum_i \left(\frac{r_i}{\mu}\right)^a - 1\right] \quad (11)$$

The values of GE measures vary between 0 and ∞, with zero representing an equal distribution and higher value representing a higher degree of inequality. The parameter $a \in \mathbb{R}$ represents the weight given to distances between shares in different parts of the fish shares distribution. Lower values of a indicates that the measure is more sensitive to changes in the lower tail of the distribution and vice versa for higher values. The $GE(1-\varepsilon)$ is the A index, while the $GE(2)$ yields an index that is cardinally equivalent to Herfindahl index and finally the $GE(1)$ is commonly known as the Theil index (Cowell 2011).

In turn, we examine the relative stability of different allocation rules by using a stability measure, known as Power Index (PI). The PI is often used for selecting stable solutions for cooperative problems in cases where the involved partners are negotiating an agreement (Loehman et al. 1979; Dinar and Howitt 1997; Madani and Dinar 2012). For allocation problems the PI for the i partner can be written as (Read et al. 2014):

$$a_i = \frac{w_i\left(r_i^{\max} - r_{ik}\right)}{\sum_i w_i\left(r_i^{\max} - r_{ik}\right)} \quad (12)$$

where w_i is the long-run average fish share of the i country and $r_i^{\max}$ denotes the maximum claim of the i country across all the scenarios. (Dinar and Howitt 1997) propose to measure the stability of the group decision of a cooperative problem as the coefficient of variation, $CV = \frac{\sigma}{\overline{a}}$ estimated across all players for a given scenario. Note that σ denotes the standard deviation of the set of a_i and $\overline{a}$ is the average power index. Low values of CV indicates greater stability and vice versa.

2.3 The Index of Social Envy

These two criteria, namely fairness and stability, yield two different sets of qualified alternatives, those that are fairer than the ICCAT' rule and those that are more stable than the ICCAT's rule. In turn to the members of the intersection of these sets we estimate the index of social envy to get the final solution. The index of social envy (ISE), proposed by Chaudahuri (1986), can be written as:

$$ISE = \sum_i E_i\left(r\right) \quad (13)$$

where

$$E_i\left(r\right) = \sum_k \frac{\left(\hat{r}_i - r_{ik}\right)}{r_{ik}} \quad \forall r_{ik} < \hat{r}_i \quad (14)$$

where $\hat{r}_i$ denotes the ICCAT's share for the i country.

3) Results and brief discussion

The next table presents the estimated inequality indices for the possible scenarios examined.

Table 1: Inequality across possible allocation rules

	PR	**CEA**	CEL	TALM	**Amin**	AP	**AP-CE**	ICCAT
Atkinson (e=0.5)	0.495	0.482	0.614	0.541	0.492	0.512	0.4	0.501
Gini	0.741	0.732	0.774	0.764	0.74	0.754	0.658	0.747
Generalized Entropy (θ=0.5)	1.157	1.122	1.151	1.29	1.149	1.2	0.901	1.173

On the basis of these results the set of the qualified fairer allocations comprises the PR, the CEA, the Amin and the AP-CE rules.

The following Table displays the stability indices of the possible alternatives

Table 2: Stability indices for the possible allocation rules

	PR	CEA	**CEL**	**TALM**	**Amin**	**AP**	AP-CE	ICCAT
CV	**2.751**	3.356	**1.331**	**1.167**	**2.783**	**1.161**	3.976	2.817

From Table 2 it is clear that the second set, that of the more stable alternatives, comprise the PR, the CEL, the TALM, the Amin, and the AP rule.

Consequently, in the intersection of these two sets belong only the PR and the Amin allocation rules. Finally, we estimated the ISE indices for these two candidates, the values of which are given in the following Table.

Table 3: The comparison between PR and Amin based on the ISE index

	PR	**Amin**
ISE	1.965	**1.882**

From Table 3 it is evident that the Amin rule is the chosen allocation rule which compromise fairness and stability. Such a result was somehow anticipated since it is shown by Giménez-Gómez and Peris (2014) that the Amin rule Lorentz dominates the proportional solution. It is noteworthy that the Amin rule represents a specific combination of two focal rationales in the sharing problems. The first rationale put forward by the equal shares method can be seen as a “leftist” approach since it modifies the existing relative inequalities of the countries’ entitlements. By contrast, the proportional sharing can be interpreted as a “rightist” approach since it preserves such relative inequalities. The terms “rightist” and “leftist” are due to Kolm (1976).

The selected rule is characterized by the property of resource monotonicity, super modularity, order preservation as shown by Giménez-Gómez and Peris (2014), which guarantees that such a solution remain consistent and valid if the resource availability changes.

Conclusions

The paper challenged the appropriateness of the relative stability used by ICCAT. We considered a set of alternatives allocations originated by the bankruptcy literature and we used fairness and stability criteria to evaluate these alternatives against the ICCAT's rule. As it was anticipated fairness and stability do not coincide. Only two possible allocation rules are found to be fairer and more stable than the ICCAT's rule, the equal proportional and the Amin. The dilemma of choosing between them was resolved by using the concept of social envy. By minimizing the index of social envy, it was found that the solution which successfully reconciles stability and fairness is the Amin.

The main result obtained is that the allocation rule which is defined as the weighted average of equal proportional and equal share rationales is the preferred one. Such a result can be interpreted as a compromise solution in terms of the "rightist" and the "leftist" solutions in Kolm's (1976) terminology. Finally, the selected allocation rule is easy to implement, and is characterized by very interesting properties.

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Using a general equilibrium model to evaluate first mover advantage in climate policy

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Abstract
The aim of the paper is to analyse the macroeconomic costs and benefits for the EU as a first mover in climate change mitigation. A general equilibrium approach is followed using the GEM-E3-RD global multi-sectoral model enhanced with endogenous technology learning mechanisms. The EU is faced with an important dilemma: Does it undertake immediately a strong effort towards decarbonisation of the EU energy system in the hope that other countries will eventually join or does it delay such action until an international consensus has been reached? In exploring this question a number of scenarios using the GEM-E3-RD model have been evaluated. The Reference scenario represents a situation where climate policy is limited to current commitments of the different countries of the world. The EU Alone scenario assumes that a unilateral EU action is taken and the world fails to follow suit before 2050. A third scenario assumes global delayed climate action until 2030 and strong decarbonisation action after 2030. Finally a first mover scenario was evaluated assuming that the EU undertakes early action and the world joins it after 2030. The model results show that first mover action drastically diminishes European mitigation costs due to a prolongation of the decarbonisation period and the increased exports of clean energy technologies. Early action sets into motion R&D effort on clean energy technologies which combines with economies of scale (learning by doing) obtained by drastically increased uptake within the EU leading to cost reductions. Such reductions can to some extent be appropriated by European industries leading to competitive advantage in global markets for clean energy technologies, which can be particularly important in case of strong mitigation policies in non-EU regions after 2030. The model projections show that electric vehicles, CCS and photovoltaics are the key technologies that can generate large benefits in case of European first mover climate action.

Keywords: First mover advantage, General equilibrium model, endogenous growth, fragmented climate policies

Introduction

In the last two decades climate change has emerged as one of the great global policy challenges, as it is increasingly recognized that unabated climate change can have large impacts on human societies and economic development. In the last UNFCCC conferences of parties, most countries made pledges to reduce their GHG emissions (or GHG emissions intensity of GDP) by 2020. However, the emission pledges made by the major carbon emitting economies are not binding and not ambitious (as assessed UNEP (2013)). As a result, emphasis has shifted towards regionally asymmetric climate policies and the integration of other policy priorities, such as uptake of low carbon technologies, security of energy supply, innovation through R&D, industrial competitiveness and economic development.

The EU leads the global effort for climate change mitigation, as it has already adopted a binding target to reduce its GHG emissions by 20% relative to 1990EC(2009), established the world's largest emissions trading system (EU-ETS) and has implemented a number of additional energy and climate policies at national level. Furthermore, the European Union confirmed its long-term objective to reduce its GHG emissions by 80-95% compared to 1990 levels by 2050 (EC (2014)) Recently, the European Commission adopted the 40% GHG emissions reduction target by 2030 that is considered to be in line with the long term decarbonisation target (EC (2014)), (Capros et al 2014).

A central concern for the EU policy makers is what would be the macro-economic implications in case that Europe unilaterally adopts strong decarbonisation policies without an international agreement on GHG mitigation in place. Decarbonisation for the EU generally involves substitution of imported fossil fuels by domestically produced goods and services, which are used to improve energy efficiency and implement emission reduction technologies. Higher energy prices due to strong carbon pricing constitute a challenge for trade-exposed European energy-intensive industries (Paroussos et al 2014), while decarbonisation is considered to have a positive impact in energy efficiency services and in the agricultural sector due to higher demand for bioenergy.

Computable General Equilibrium (CGE) models have been extensively used to assess the macro-economic and sectoral implications of alternative climate policies. GEME3-RD represents comprehensively the economic production and trade of goods with high sectoral resolution and accounts for the complex interactions between the energy system and the overall economy (Capros et al 2014). Climate policies and measures implemented in a group of countries (e.g. in the EU) would also affect other countries, as economies are interconnected through multiple channels, including trade in goods and services, trade of fossil fuels, knowledge and technological spillovers and financial flows. The main impacts of asymmetric climate policies include (Enrica De Cian et al 2013):

- **Energy market effect:** increase of energy consumption in non-abating countries induced by lower international fossil fuel prices due to emission reduction, hence lower fuel consumption, in the carbon abating regions (EU)
- **Industry relocation:** energy intensive production partly shifts from the EU to regions that do not implement climate policies due to changes in relative costs of production (Paroussos et al 2014)
- **Technology innovation and diffusion:** The imposition of climate policy in a region increases its energy prices and thus stimulates innovation and diffusion of low carbon technologies to other parts of the world (Carraro 2010)

Energy system and general equilibrium integrated assessment models (IAMs) usually represent some of these channels. De Cian et al (2013) confirm that in the suite of 8 IAMs they employed, there is no single model that describes all three channels. On the other hand, GEME3-RD represents endogenously all international mechanisms discussed above and thus it is particularly well equipped to quantify the macro-economic impacts of asymmetric climate policies. Another effect that has not been explicitly captured by any macro-economic model so far (Enrica De Cian et al 2013) concerns the potential domestic industry effects that being a global technology leader might bring about. In order to evaluate the possibility that the EU becomes a leader in clean energy technologies and sells them to other regions, GEME3-RD has been enriched with a separate representation of the most important clean energy producing industrial sectors. The model also includes endogenous technological change mechanisms for zero carbon technologies through both learning by experience and learning by R&D and innovation.

The objective of the study is to explore whether the European economy can get first mover advantages, at least partially for some sectors, by pursuing ambitious climate targets earlier than other regions or whether it would be preferable that the EU waits to synchronize carbon abatement actions with the rest of the world. Towards this end, we evaluate a series of alternative scenarios that assume asymmetric climate policies with the GEME3-RD model, which constitutes the first large scale CGE model that projects endogenously the production and global trade of clean energy producing sectors, while it incorporates a detailed representation of the energy system and endogenous technology dynamics mechanisms. All mechanisms are embedded within the strict specification of general equilibrium modelling.

The GEME3-RD model

GEME3-RD (Capros et al 2012) is a global, multi-region, multi-sectoral, recursive dynamic CGE model that covers the interactions between the economy, the energy system and the environment and provides quantitative results until 2050 in five-year steps. GEM-E3 covers the entire economy and can evaluate consistently the effects of energy and climate policies on economic activity, national accounts, investment patterns, domestic consumption, public finance, balance of trade and employment in the various economic sectors and agents.

The regions explicitly identified in GEM-E3-RD include both developed (the EU-28 region, North America, OECD Pacific) and emerging economies (China, Energy Exporters, rest of the world). The model covers all production sectors aggregated to 38 (Table 1) and economic agents (firms, households, government).

The GEM-E3-RD model computes the equilibrium prices of goods, services, labour, energy and capital that simultaneously clear all markets under the Walras law (global closure). It formulates separately the supply and demand behaviour of the economic agents which are considered to optimize individually their objectives, while market derived prices guarantee global equilibrium. Productive sectors operate within a perfect competition market regime and maximize profits, while household demand, savings and labor supply are derived from utility maximization of households assuming exogenous demographic developments. The regions of the model are linked through endogenous bilateral trade following the Armington specification (1969), according to which domestically produced and imported commodities are considered to be imperfect substitutes. The labour market is modelled following the efficiency wages approach (Shapiro and Stiglitz 1984) which allows for non-voluntary unemployment and flexibility in wages.

Households purchase goods and services for various purposes from which they are assumed to derive utility. Some of these goods and services are consumed directly, whereas others are consumed through the use of durable goods, such as houses, appliances and cars. The GEME3-RD model distinguishes between durable and non-durable goods and links the consumption of goods and services to the use of durable goods. The stock of durable goods changes dynamically over time due to investment of households in new durable goods (which are determined endogenously).

Table 1: GEM-E3-RD Sectors

Code	Sector	Code	Sector
01	Agriculture	20	Production of Ethanol
02	Wheat, Cereal Grains, Sugar cane, sugar beet	21	Production of Bio-Diesel
03	Oil Seeds	22	Coal fired power generation
04	Coal	23	Oil fired power generation
05	Crude Oil	24	Gas fired power generation
06	Oil	25	Nuclear power generation
07	Gas	26	Biomass power generation
08	Electricity supply	27	Hydro-electric production
09	Ferrous and non-ferrous metals	28	Wind power generation
10	Chemical Products	29	Photovoltaics power generation
11	Other energy intensive	30	CCS Coal power generation
12	Electric Goods	31	CCS Gas power generation
13	Transport equipment	32	R&D services
14	Other Equipment Goods	33	Production of Wind
15	Consumer Goods Industries	34	Production of PV
16	Construction	35	Production of CCS
17	Transport	36	Production of Electric Vehicles
18	Market Services	37	Production of Advanced energy efficient equipment
19	Non Market Services	38	Dwellings

The GEME3-RD model includes a bottom-up representation of the energy system, which is described in brief below:

- **Power generation**: Electricity producing technologies identified in the model (coal, oil, gas, nuclear, wind, biomass, solar, hydro, CCS coal and CCS gas) are treated as separate production sectors (sectors 22-31 in Table 1). Competition of technologies to cover electricity demand is determined by their generation costs, which include investment, operating and maintenance and fuel costs. Capital costs depend on both learning by doing and learning by research effects.
- **Transport:** Households are assumed to decide between public transport and the use of private vehicles. The model represents the competition between electric and plug-in hybrid cars with conventional private cars.

- **Energy demand of households:** Advanced energy-saving equipment that uses a variety of fuels (coal, oil, natural gas, biomass, electricity and renewables) competes with conventional equipment to satisfy heating, cooking and electricity demand of households.
- **Energy efficiency investment:** Substitution between fuels towards more efficient options and substitution between energy and non-energy inputs (e.g. substitution of energy with capital, labour and materials) directly lead to energy efficiency improvements. Firms and households are modelled to have the possibility to invest in energy savings, instead of other investments. The effect of cumulative energy investments on energy productivity exhibits diminishing returns to scale. Investments in energy efficiency improvement are incited by high carbon prices but can be also driven by specific energy efficiency promoting policies.
- The **carbon price** is determined endogenously at an economy-wide level so as to meet the given emission reduction target in each scenario for each region identified in the model.

In order to quantify the competitive advantage that the EU can get by adopting strong climate policies earlier than other regions, the equipment production sectors were split to separately represent production of the most important clean energy technologies, including wind turbines, photovoltaics, CCS, electric vehicles, advanced energy efficient household equipment and production of biodiesel and ethanol. The new production sectors were consistently introduced in all Input-Output tables, the investment matrices and the bilateral trade matrix of the model. The agriculture sector has been split into sectors producing feedstock for food and other purposes and sectors producing feedstock for biofuels (production of biodiesel and ethanol are distinguished). The representation of these new sectors in the model and the compilation of consistent data for their regional production and global trade represents a considerable challenge as it must be embedded with the strict specification of the CGE modelling framework.

Endogenous technical progress has been incorporated in the model in the form of two factor learning curves (Kouvaritakis et al 2000). In this specification, cost improvements of clean energy technologies depend on their cumulative production (learning by doing effect) and on the cumulative R&D stock (learning by research). Appropriate learning rates have been introduced for zero carbon technologies. Knowledge diffusion and spillovers between regions are also represented in GEME3-RD.

The R&D sector is modelled separately and provides its services to firms, households and government (public R&D). Production functions of clean energy producing sectors are assumed to be Constant Elasticity of Substitution (CES) functions and exhibit a nested scheme, involving capital (K), labour (L), energy (E), materials (M) and R&D. At the top level the producer decides on R&D expenditures. Investments in R&D are determined by the production nested scheme and depend on the R&D cost relative to costs of other production factors. R&D expenditures are translated into a cumulative “stock of knowledge”, which determines learning by research for zero carbon technologies. Appropriate depreciation rates of R&D have also been established.

Clean energy technologies have a large potential for cost reduction if developed at a large scale as a result of R&D expenditures and economies of scale in mass production.

The imposition of strong emission reduction targets in GEME3-RD leads to higher deployment of zero-carbon technologies. Higher demand for clean energy equipment implies more production, hence higher learning and bigger productivity gains that can be increased further due to additional R&D expenditures. In case such learning progress takes place only in one region (e.g. in the EU), this region gains a competitive advantage and thus a higher market share in global trade for these technologies.

Scenarios quantified with the GEME3-RD model

The study involves comparisons of model results for a sequence of four scenarios with the objective to quantify the conditions that enable the EU to get First Mover Advantage in the case of unilateral climate action. The four scenarios examined in the analysis include (Table 2):

- ***The Reference Scenario (Ref)*** that assumes continuation of fragmentation in regional climate policies to 2050. The regions implement the low end of their Copenhagen-Cancun pledges and the targets for RES deployment up to 2020 and continue to improve their carbon intensity of GDP in the period 2020-2050 at rates comparable to their action in the period 2005-2020. This scenario is consistent with the moderate climate policy reference scenario of the AMPERE project (Kriegler et al) and the reference scenario for Europe of the Energy Roadmap 2050 [3], (Capros et al 2014).
- ***The 450 ppm mitigation scenario with delayed action until 2030 (450delay),*** where a cumulative global carbon budget (consistent with keeping the GHG atmospheric concentration below 450 ppm) is imposed as a constraint in the period 2030 to 2050 (Kriegler et al). Before 2030, the models follow the reference scenario assumptions. Europe meets the carbon budget of the period 2010-2050 as specified in the Roadmap 2050 [3].
- ***The EU Alone decarbonisation scenario (EU-alone***), where Europe is assumed to adopt stringent emission reduction action from 2015 in line with the EU Roadmap targets, while non-EU regions implement the climate policies of the Reference scenario.
- ***The EU as a First Mover in climate policy until 2030 (EU-FMA),*** which assumes that the other world regions join the stringent unilateral EU decarbonisation action (in line with the Roadmap targets) in 2030. The scenario assumes that the global carbon budget of the 450 ppm target is met in the period to 2050.

- ### Scenario Results
  - #### Global market for clean energy producing sectors

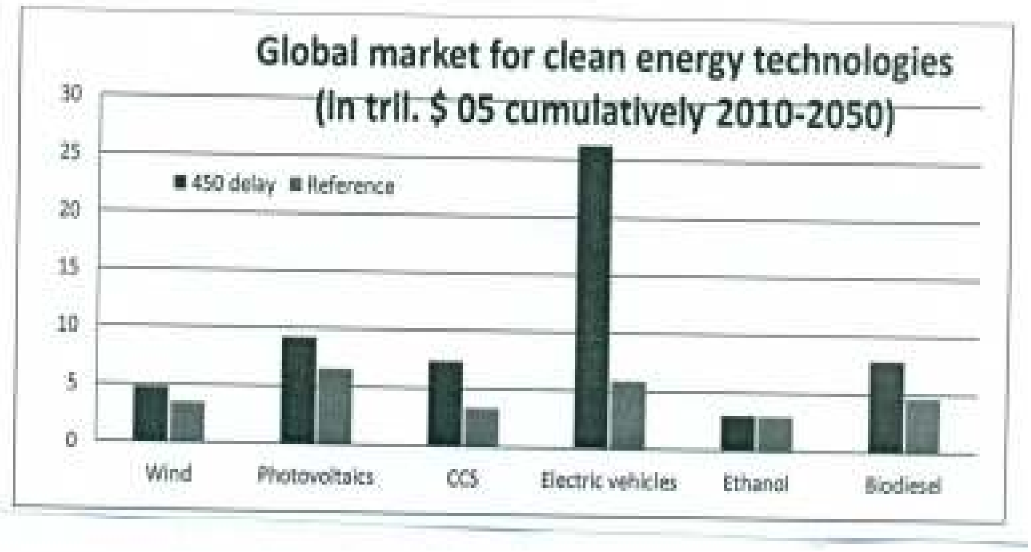
At present, the sectors producing clean energy technologies represent a relatively small share of global economic activity (0.1% of world GDP in 2010). However, there is a large potential for expansion of clean energy production under the Reference scenario assumptions. The expansion of these sectors would be even more rapid in the case of strong mitigation policies, as the relative competitiveness of clean energy technologies compared to fossil fuel alternatives increases leading to massive deployment of zero carbon options (Figure 1). In the 450-delay scenario, the global market for clean energy technologies is projected to amount to 62 trillion $05 (cumulatively over 2010-2050)

which is equivalent to 1.6% of cumulative global GDP. Their relative importance is even higher for the EU region as they account for 3.1% of its cumulative GDP.
The major impact of the 450 scenario occurs in electric and plug-in hybrid vehicles, which are deployed very modestly in the Reference scenario but become essential in the mitigation context. They tackle the issue in the important road transport sector, which accounts for nearly 20% of global carbon emissions in 2010 and is not amenable to many other mitigation options.

Table 2: Scenarios specifications

Scenario Type	Scenario name	Global Target	EU 2050 target	Climate policy until 2030	Climate Policy in 2030-2050
Reference policy	**Ref**	None	Reference targets	Derived from regional reference climate targets	
Delayed 450 action	**450delay**	450 ppm	EU Roadmap	Reference scenario	EU Roadmap, others 450 target
EU alone scenario	**EU-alone**	None	EU Roadmap	EU follows the Roadmap, others the reference scenario until 2050	
EU as a First Mover	**EU-FMA**	450 ppm	EU Roadmap	EU Roadmap, others Ref	EU Roadmap, others 450 target

Figure 1: Global market for clean energy technologies (2010-2050)



Consequently, electric vehicles constitute the most important mitigation option in economic terms with a global market of 26 trillion $05 cumulatively. The reference scenario already implies a sizeable industry for wind turbines, which are a relatively mature technology implying limited potential for further cost reductions and therefore the impact of the scenario is relatively modest. The cumulative market of photovoltaics is projected to amount to about 10 trillion \$05 in the mitigation scenario. Biodiesel sees a marked increase especially as mitigation takes place after 2030 when lignocellulosic options are widely available. The latter explains the insignificant impact of the scenario on ethanol production. Another mitigation option that can generate a large market under appropriate policy conditions concerns CCS. The global cumulative market for CCS more than doubles in the 450 delay scenario relative to the Reference, driven by the large potential for deployment of CCS technologies in major emerging economies such as China and India.

- **The EU position in global clean energy market**

In the EU-FMA scenario, Europe is motivated to invest in R&D in clean energy technologies early in the forecasting period and at the same time it benefits from a fast growing EU market enabling the consolidation of economies of scale and other learning by doing advantages. The European internal market is sufficiently large to allow for achieving a large part of the learning potential for clean energy options, thus leading to cost reductions. The EU is therefore well poised to gain a major slice of the global market by taking advantage of its early start at the time when world demand starts expanding very rapidly as non-EU regions join in the mitigation effort (Figure 2). Beyond 2030, this advantage is gradually eroded due to spillover effects as productivity improvements are absorbed by EU competitors. This erosion notwithstanding, the EU maintains an advantage even by 2050 arising from the consolidation of its market position in previous years.

Vehicle manufacturing is a sector where Europe already enjoys a comparative advantage in world trade and is therefore in a good position to profit from a potential huge global market, as transport electrification constitutes an essential component for the mitigation effort. Table 3 shows that electric vehicles account for 56% of the cumulative EU clean energy exports in the EU-FMA scenario. The relative maturity of wind turbines mean that the impact of the scenarios on the EU wind turbine industry is relatively small. On the other hand, exports of CCS and photovoltaics expand considerably in the EU-FMA scenario. In all scenarios the EU undertakes no exports of biofuels to the Rest of the world as Europe is a high-cost producer requiring subsidies for domestic production. The European early advantage combined with the large global market mean that EU exports of clean energy equipment account for 11.2% of the cumulative (2015-2050) European exports in the EU-FMA scenario, while the share is more than 18% in 2050.

- **Macroeconomic implications of the scenarios**

The imposition of strong climate policies is simulated by high carbon pricing that induces changes in the economy driven by substitution away from fossil fuels and lower energy consumption per unit of economic activity. Higher investments are required to enable these changes as clean energy technologies are capital intensive. The changes away from fossil fuels are costly and energy services become more expensive in all sectors compared to the Reference. The increased costs of energy services imply lower purchasing power of private income and thus lower demand and higher prices in the supply of goods and services leading to further decrease of demand. The additional mitigation-related investment lead to increased demand for goods and services that are needed to produce the new efficient equipment, low carbon power plants, electric vehicles, biofuels and for insulating buildings. The numerical simulations in this paper, in agreement with the literature (Capros et al 2014), (Enrica De Cian et al 2013), (Kriegler et al), find that the net effect on GDP is negative relative to Reference (Table 4) despite induced technological progress, as additional clean energy investments are not found to be sufficiently high to offset the activity depressing effects stemming from higher production costs.

Figure 2: Share of EU production in global market for clean energy technologies (in %)

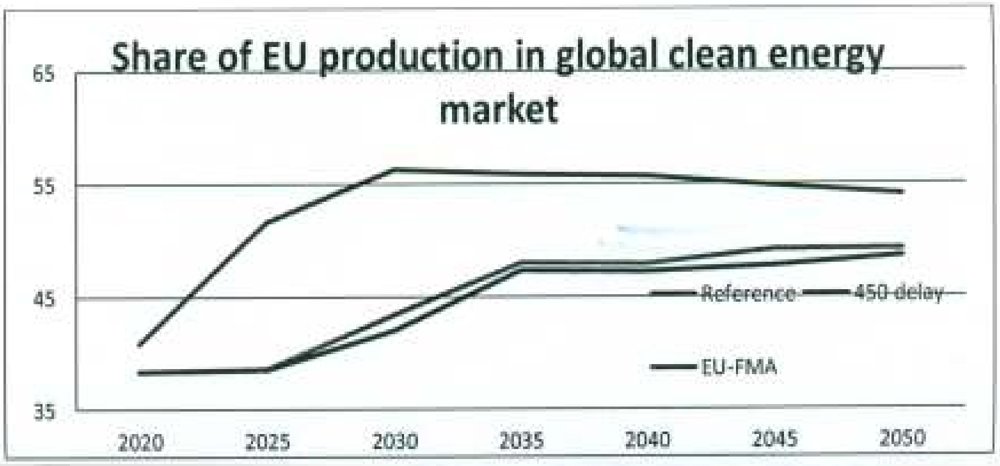


Table 3: Cumulative EU exports of clean energy equipment (in bn. $ 05)

	Reference	450-delay	EU-alone	EU-FMA
Wind turbines	438	593	468	613
Photovoltaics	1270	1971	1771	2347
CCS technologies	1215	2111	1523	2682
Electric vehicles	1031	5162	2253	7630
Energy efficient equipment	244	260	260	302
Biofuels	0	0	0	0
Clean energy production	**4198**	**10097**	**6276**	**13574**
Share in total EU exports	**3.5%**	**8.5%**	**5.3%**	**11.2%**

The increases in unit production costs in the EU-Alone scenario relative to Reference due to high carbon pricing exert a negative impact on the EU balance of trade leading to a reduction in exports (-0.5%) and an increase in EU imports (0.3%). Cumulative EU GDP losses are projected to amount to 0.5% in 2010-2050. The 450-delay scenario leads to higher GDP losses in the EU despite the relative improvements in the balance of trade relative to EU-alone. This is due to the depressive effect of the scenario on global GDP (-1%), as the EU bears the consequences of global activity reduction. Increases in production costs in other regions imply that EU imports become more expensive. To the extent that these imported goods are used to produce final goods in the EU, the 450-delay scenario leads to increases in EU production costs, which further compress the EU's domestic demand. Another reason is related to the shorter time in which the EU has to meet the same decarbonisation target ("delayed action"), as economic substitutions need to become more intensive resulting in much higher carbon prices and production costs in the period 2030-2050.

The burden of carbon pricing in the economy depends on the degree of carbon intensity (GHG emissions per unit of GDP) and on the marginal emissions reduction costs of the model regions. Developed regions have lower carbon intensities compared to developing and this mainly explains that GDP losses are projected to be higher in the latter when applying equal carbon prices. Furthermore, the imposition of equal carbon prices implies higher relative increases in energy prices of the developing regions. In the 450-delay scenario, the highest GDP losses are found in Energy Exporters (-2.1%) as a result of reduced oil and gas revenues. On the other hand, the model results show that the induced technology progress implies higher exports by developed countries (especially North America) to developing regions, which tend to mitigate depressive GDP effects.

Additional investments in capital-intensive low carbon technologies that substitute fossil fuel consumption lead to increases in overall investments in decarbonisation scenarios in all regions, while the reductions in private consumption are found to be higher in magnitude than GDP losses. The impacts of the mitigation scenarios on employment are relatively small. This is the result of two opposite trends: (i) GDP reduction that implies lower employment (ii) high labour intensity of the clean energy producing sectors relative to fossil fuel alternatives.

The results of the EU-FMA scenario show clear economic benefits for the EU compared to EU-Alone and 450-delay scenarios stemming from the fact that decarbonisation action starts earlier and is spread over a prolonged period of time. Induced technology progress also plays a marked role in alleviating the negative economic impacts, provided that the EU uses the internal market to capture a considerable part of the learning potential of clean energy technologies. In this case, the EU consolidates a competitive advantage in the large global market for clean energy technologies that leads to increased overall EU exports in other regions (which are 1.4% higher than in Reference in cumulative terms).

Table 4: Macroeconomic implications of scenarios (in % changes from reference)

	EU-alone		450-delay		EU-FMA	
	EU-28	**Non-EU**	**EU-28**	**Non-EU**	**EU-28**	**Non-EU**
GDP	-0.51	-0.02	-0.60	-0.95	-0.20	-0.97
Investment	0.15	-0.03	0.13	0.63	0.02	0.64
Private Cons.	-0.77	-0.03	-1.16	-1.60	-0.61	-1.63
Exports	-0.53	0.25	-0.23	-1.00	1.37	-0.21
Imports	0.28	0.13	-0.46	0.96	0.38	2.13
Employment	0.01	0.00	0.00	0.01	0.02	0.01

Conclusions

The aim of the quantitative projections conducted is to analyse the macroeconomic costs and benefits incurred by the EU as a first mover in climate policies and identify the possible First Mover Advantages that the European economy can get. A general equilibrium approach is followed using the GEM-E3-RD model enhanced with bottom-up energy system representation, endogenous technology dynamics for low carbon options (through learning by doing and learning by research) and separate representation of clean energy producing industrial sectors. A series of scenarios have been quantified, which are compared with the Reference projection to 2050.

The model results show clear advantages for the EU as a first mover in climate change mitigation compared to a delaying of climate action provided that in all cases the EU has to meet the same carbon budget. If the EU waits until 2030 to synchronise climate action with other regions, EU cumulative costs in 2010-2050 increase threefold. Early EU climate action sets into motion R&D effort on clean energy technologies which combines with learning by doing obtained by increased uptake within the EU leading to cost reductions for zero carbon technologies assuming that the European internal market is sufficiently large to allow for achieving a large part of learning potential for clean energy technologies.

In case that rest of the world will join the ambitious EU effort in 2030, Europe can get important economic benefits arising from the prolonged period for the energy system restructuring and the competitive advantage in global markets of clean energy technologies. The most important among these technological options is electric vehicles that constitute an essential ingredient of decarbonisation with a large potential global market by 2050. Other decarbonisation options that can generate a large market under appropriate policy conditions concern CCS and photovoltaics. Despite the relative erosion of the first mover advantage in the long term due to spillovers to other regions, EU exports of clean energy technologies are projected to increase considerably above Reference levels. This leads to increased levels of exports, employment and economic production compared to the delay scenario.

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A regional model for analysis and visualization of the synergistic impact mechanism of climate related costs

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Abstract
One climate related phenomenon could affect many more. The direct costs associated to climate related factors pass to a number of other climate related costs through the indirect economic consequences of climate change. In this paper we propose a mathematical model which aims to provide forecasts of the distribution of the costs caused by the synergistic mechanism of environmental effects. The model is created to be directly applied to situations where the primary costs associated to climate related factors can be specified. It is expressed in matrix terms and is programmed using *Mathematica*'s matrix functions. We provide the framework for efficient computation of this model, covering possible linear and nonlinear functions of the impact mechanism for costs and, infinite direct cost scenarios. Some directions for the quantitative estimation of impact indicators and adaptation potentials of the costs incurred by certain climate related factors are included, in order to apply the proposed model using real socioeconomic data.

Keywords: Computational techniques; *Mathematica* computer software; Climate change related factors; Cost interactions.
JEL Codes: Q54; Q50; Q58; C63; C88.

1. Introduction

Societies depend entirely on ecosystems and the associated offered services like, among others, water and food provisions, operating in global biogeochemical cycling, raw materials and regulation of the climate (Dixon 1986; Barbier 1994; MEA 2005). The global climate change is a very complex issue and it is even more difficult to tackle and cope with due to its long-run character and the various synergistic effects stemming from its impacts.

The synergistic impact mechanism of environmental effects produces the «colliding steel spheres effect», meaning that one climate related phenomenon could affect many more. In many environmental studies it is claimed that parallel interactions among climate effects is a possible situation (IPCC, 2001; 2007; 2012 a,b; Fűr and Csete, 2010; Mantyka-Pringle et al., 2012; European Commission SWD, 2013). In the report published by IPCC (2001) climate change impacts are presented and analyzed on a matrix of potential for interactions and synergistic effects.

In the present study we generate visual schemes of the direct synergistic effects between climate related factors in several human settlement and industry types. Considering the primary costs caused by climate related factors, we assume that the synergistic impact mechanism among certain climate related factors allows for a similar synergistic impact mechanism of the corresponding primary costs.[39] With notations and operations of matrix algebra, using either a technical coefficient or a functional matrix to illustrate climate related cost interactions and synergistic effects, we formulate a local scale model that forecasts the cost distribution which the direct synergistic mechanism causes from the direct costs of certain climate related factors.

We create the computational framework to apply the proposed model in a qualitative and a quantitative approach. For this purpose a main computer algebra system, *Mathematica*[40] is used to generate our model's output, both visually and numerically. Specifically, in *Mathematica*'s computational environment, we create pattern constructs consisting of colored patches which describe the synergistic impact mechanism of climate related factors.

In this way, we provide initially a concise framework for synthesizing and displaying the data on an area's human-economic system. Then our predictive model is applied by using hypothetical data and *Mathematica*'s dynamic visualization options, in order to generate versions of cost distribution snapshots, with controls added to allow interactive manipulation for the value of impact indicators of cost interactions, the synthesis of the direct cost distribution and the amount of costs. Our model and its computational aspects allow for clear visual comparisons among certain settlement and industry types. The proposed model is well suited to perform sensitivity analyses in cases of settlements and industries and also to evaluate climate policies.

Finally, our contribution provides directions for quantitative estimates of impacts and adaptation potentials of the costs incurred by climate change related factors. It also ensures the model's applicability guiding for future applications on the economic costs of certain ecosystem inputs like migration, flooding-landslides-fires, air and water pollution, human health and energy by the use of available appropriate socioeconomic data.

The structure of the paper is the following. The next section discusses the visualization of the interactions first in the case of different settlement types and next to industry types. Section 3 proposes a linear and nonlinear cost analysis with different climate change scenarios and derives indicative estimates of the potential costs. Section 4 provides some insights in terms of performing an empirical application of the proposed model formulation while the last section concludes the paper.

2. Visualizing the interactions among climate related factors

2.1 The case of settlement types

Humans depend on the ecosystems and they are part of the ecosystems they live on (Wilson 2002; Puglise & Kelty 2007). Obviously a healthy ecosystem has the ability to sustain healthy human populations (Rapport et al. 1998). Most of the population in Earth lives in settlements in a way that their concentrations may result to vulnerabilities to local

[39] Primary costs may be identified as direct costs while secondary costs may be considered as synergistic.
[40] *Mathematica* software is tradable from Wolfram Research, Inc.

specific events. Vulnerability refers to the way a system reacts to the degradation imposed from its exposure to various risks.[41]

Human settlements and coastal zones are influenced significantly by coastal and riverine flooding, fires, etc. The risks and uncertainties of the consequences of global warming are of interest. The sea level rise will influence coastal areas and the use of land and may threaten the survival of some coastal communities. Extreme weather conditions and patterns leading to heat waves, floods and droughts change the climate condition of some areas with resulting consequences like storms appearing more often and more intensively.

The higher weather variability and the more extreme events may also affect the energy sector by increased demand for air-conditioning and reduced demand for space heating. This may be accompanied by the concern of electricity producers related to the reliability of their systems to cope with these changeable weather conditions (Kolstad and Toman, 2005). Similarly, water infrastructure will be at risk with changes in precipitation to question the ability of the current infrastructure of dams and reservoirs (Kolstad and Toman, 2005).

If extreme weather conditions remain then some local areas will face problems to sustain the existing population resulting to migration and dislocation. The effects are serious and may range from loss of land and coastal flooding from the sea level rise, health problems with more deaths and tropical diseases, increased storms and floods to migration. Flooding may be considered as one of the most serious effects of climate change on human settlements with riverine and coastal settlements to be at high risk (IPCC, 2001).

IPCC (2001) presents a matrix of synergistic effects between climate associated factors influencing human settlements and industry types.[42] In our proposed computational approach and in the case of urban settlements, the interactions between migration, phenomena of flooding-landslides-fires, air and water pollution, human health and access to energy – clean water and other resources necessary to sustain human settlements and their populations are featured in a 5×5 matrix (Figure 1). Each cell identifies a synergistic effect between the climate impact featured in the row and another effect shown in the column.

The pattern constructs of synergistic effects is created in *Mathematica*, for three types of settlements; namely, urban settlements, riverine-coastal-steeplands and resource dependent settlements, as defined in IPCC (2001, par. 7.6.2). According to IPCC (2001) *urban settlements* may suffer from flooding, storm drains and sewers or from accommodating, migrant populations and suffering from urban heat island with significantly warmer conditions compared to its surroundings with consequences to health and energy demand. Similarly, *riverine and coastal settlements* may be affected

[41] Vulnerability to effects of climate change may be defined as the degree a system, subsystem or system component experiences harm from its exposure to a perturbation or source of stress (Clark et. 2000; Turner et al. 2003; IPCC, 2007).

[42] For a detailed analysis of human settlements and the associated impacts of climate change see IPCC (2001, chapter 7).

mostly by flooding from the rise of the sea level while steeplands may become more vulnerable than landslides. Finally, *resource dependent settlements* depend on the availability of natural resources in an area (region) and on the extent that they are vulnerable to climate changes. Examples may be considered hunting and artisanal fishing communities (IPCC, 2001).

In the screenshots produced, white cells make the junction of two unrelated factors. Each colored cell illustrates an interaction between two environmental effects. In our computational approach, infinite matrices of synergistic effects can be constructed, but the tendencies or patterns of interactions observed in the systems are preserved.

Figure 1: Matrix of synergistic effects for urban settlements.
Serial numbers 1-5 correspond to the following factors:
1. Migration, 2. Flooding, Landslides, Fire, 3. Air and Water Pollution, 4. Human Health 5. Energy, Water, other Resources

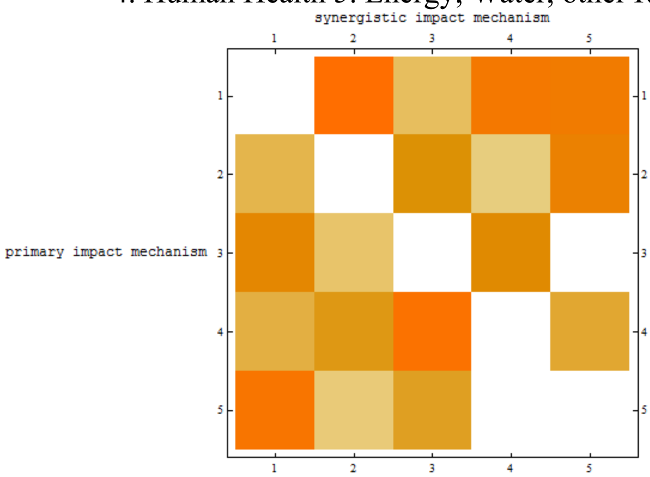
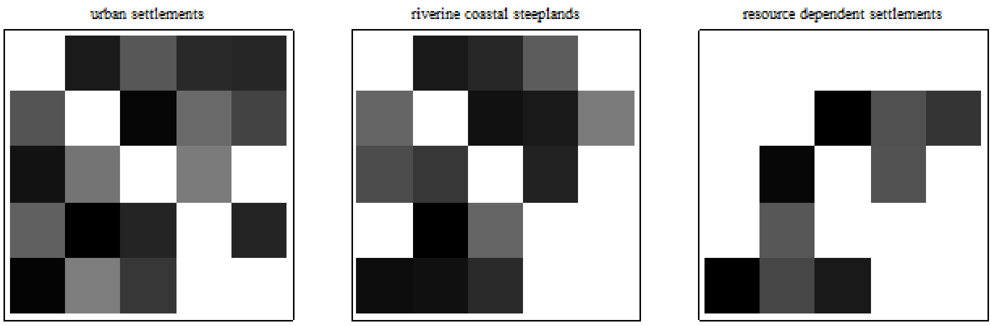


Figure 2: Matrix of synergistic effects for settlements:
Urban settlements, riverine coastal steeplands and resource dependent settlements



In Figures 2 and 3, in a different visual output in *Mathematica* matrix, cells with different shades of gray state the degree of impact of the synergistic effects. A darker shade is related to a more intensive impact. In the pattern constructs below, white cells are steadily white, while all the other cells vary their shades regionally, depending on the geographic, seasonal and/or sectoral scale. Rows and columns of matrices in Figure 2 feature the same environmental effects as in Figure 1, with the same serial number from 1 to 5. The matrix patterns produced are indicative of every type of settlement. The sparsest matrix corresponds to resource dependent settlements. This dependence is more possible to intercept the progression of the mechanism to manage environmental effects.

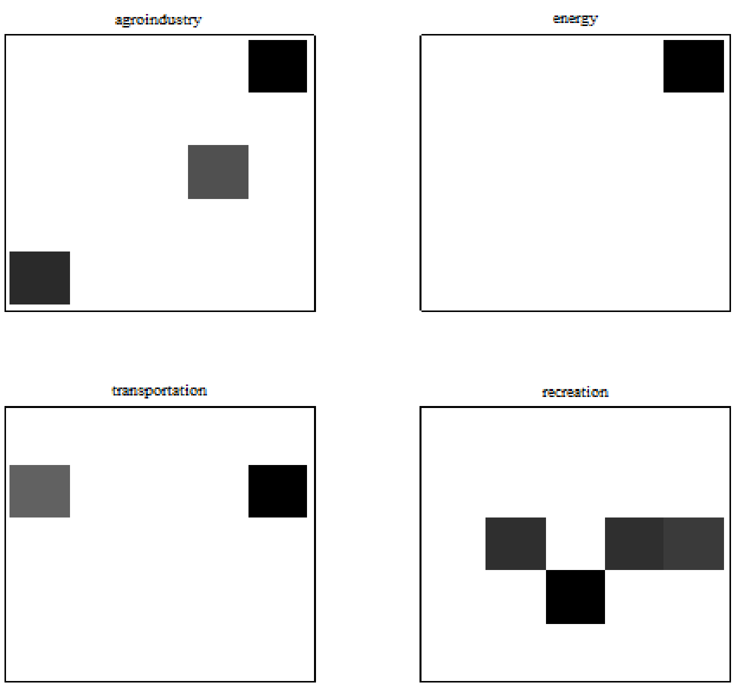
2.2 The case of four industry types

Following IPCC (2001) four industries are considered as reference:

- *Agroindustry* as one of the most adaptable industry affected by climate change with ability to adaptation varying among areas (regions) and groups of farmers within areas (regions);
- *Energy supply and demand* will be influenced with hydropower generation being the most affected and solar energy to depend on cloudiness.
- *Transportation* may be affected by floods, drier climate conditions resulting to heavy rains, by warmer climates softening the asphalt roads and by adverse weather conditions leading to flight cancellations.
- *Recreation and tourism* as a growing industry in many countries which may be affected significantly and in different ways by changes in climate precipitation depending on whether we refer to summer or winter oriented destinations.

In the pattern constructs for industry types, a white cell indicates no interaction while grey-shaded cells indicate interactions of variant influences. Rows and columns of matrices in Figure 3 feature the same environmental effects as in Figures 1 and 2 with the same serial numbers from 1 to 5.

Figure 3: Matrix of synergistic effects for industries:
Agroindustry, energy, transportation and recreation



3. Cost Analysis with Climate Change scenarios

Our model for the types of settlements uses economic or social costs as systems' metrics. An analogous study for the types of industries could constitute a Cost-Benefit Analysis (CBA). In some cases the synergistic effects could act in a beneficial way.

In the proposed predictive model we attempt to forecast the redistribution of the direct costs associated to the five climate related factors mentioned in section 2, using matrix formulations (analogous models in Environmental Economics have been proposed by Martinez de Anguita and Wagner 2010; Stenberg and Siriwardana 2009). Next, the new cost distribution synthesis is defined and its entries are computed considering several direct cost scenarios.

3.1 Linear Interactions of climate related costs

The entries of the matrix of synergistic cost effects are indicators appropriate to evaluate cost interactions. Each indicator defines the measure of the impact between different costs. The matrix entries form the patterns presented in Figure 2, depending on the type of settlement. When linear interactions among costs of environmental effects could constitute a realistic case, multiple regression coefficients[43] could be efficient estimators of impact indicators. Indicators' exact values vary regionally, depending on the geographic, seasonal and/or sectoral scale. Indicators are of dynamic nature and are specific to the settlement and industry type.

Given the primary costs associated to one or more climate related effects, we propose a model to evaluate the costs that are generated by the synergistic impact mechanism. Our model is formulated in the matrix algebra context as follows:

$$\begin{pmatrix} c_1 & c_2 & c_3 & c_4 & c_5 \end{pmatrix} \cdot \begin{pmatrix} x_{11} & x_{12} & x_{13} & x_{14} & x_{15} \\ x_{21} & x_{22} & x_{23} & x_{24} & x_{25} \\ x_{31} & x_{32} & x_{33} & x_{34} & x_{35} \\ x_{41} & x_{42} & x_{43} & x_{44} & x_{45} \\ x_{51} & x_{52} & x_{53} & x_{54} & x_{55} \end{pmatrix}, x_{ij} \in \mathrm{R} \qquad (1)$$

where the row matrix $\begin{pmatrix} c_1 & c_2 & c_3 & c_4 & c_5 \end{pmatrix}$ consists of the direct costs associated to the five climate related factors 1-5 mentioned in section 2. $[x_{ij}]$ matrix is the matrix that captures all the repercussions between the five factors and consists of the indicators of impact. The 1×5 row matrix produced, presents the cost distribution created by the synergistic impact mechanism.

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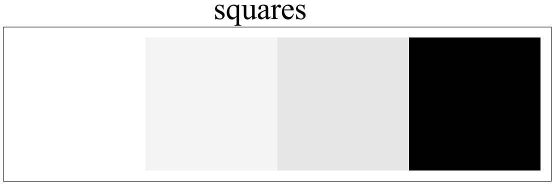
[43] These are estimates of the population parameters in a regression analysis. For each explanatory variable there is an estimated coefficient and these coefficients are used to estimate the fitted value of the dependent variable. In the case of multiple regressions, the estimated coefficients indicate the change in the mean response per unit change in the one of the independent variables holding all other independent variables constant (Halkos, 2011).

3.1.1 Cost scenarios for the types of settlements: changing distributions and costs

In the hypothetical case studies that follow, we use sample data from *Mathematica*'s random number generator to create matrices with indicators of impact for each one of the three types of settlements: urban, riverine-coastal-steeplands and resource dependent. In all hypothetical case studies examined, we assume negative impacts on economic growth (positive regression coefficients), although impacts on some areas are likely to be positive.[44]

In model (1), the direct cost distribution of climate related factors is defined in the row matrix $\begin{pmatrix} c_1 & c_2 & c_3 & c_4 & c_5 \end{pmatrix}$. In *Mathematica*'s computing environment, the product of the matrix of direct costs with the matrix of synergistic cost effects is depicted in a discrete array of squares. Thus, we have a visual representation of the structure of the re-distribution of costs of the five climate-related factors numbered from 1 to 5 (Figures 5-9). White squares indicate the absence of cost while grey-shaded squares indicate costs with nonnegative values. For example, the row matrix (0, 500, 1000, 10000) is depicted by ArrayPlot function in *Mathematica* as shown in Figure 4.

Figure 4: Visualization of row matrix (0, 500, 1000, 10000) using grey-shaded squares



Using *Mathematica*'s dynamic visualization options, we also generate the synthesis of the cost distribution that model (1) predicts, assuming an infinite number of impact indicator values: variable x parameterizes the argument in the random number generator function, making the impact indicator varying (indicatively) from 0.01 to 100 with step 1. In the first hypothetical case study, we assume direct costs incurring due to factor 2 (flooding-landslides-fires) and 3 (air and water pollution) (the row matrix (0,500,1000,0,0,0) could feature such a case). In urban settlements, these two costs pass to all the other factor costs (Figure 5), while in resource dependent settlements, the final distribution of costs does not include factor 1 (migration) cost (Figure 6). By varying the values of x, we achieve the application of model (1) for infinite matrices of synergistic effects. In all cases we end up with the same matrix structure.

[44] As global warming is mainly a long-run problem its implications are difficult if not impossible to be quantified. Human systems can adapt to climate changes in the long-run. If an area is flooded after climate change occurs migration may take place together with some form of relocation according to the new conditions which after many decades or centuries may lead to full adaptation. Thus the quantification of the consequences of this flooding is ambitious and the costs enormous. For an example see Kolstad and Toman (2005, p. 1566).

Figure 5: In urban settlements, the synergistic mechanism from c_2 and c_3 costs causes all categories of costs

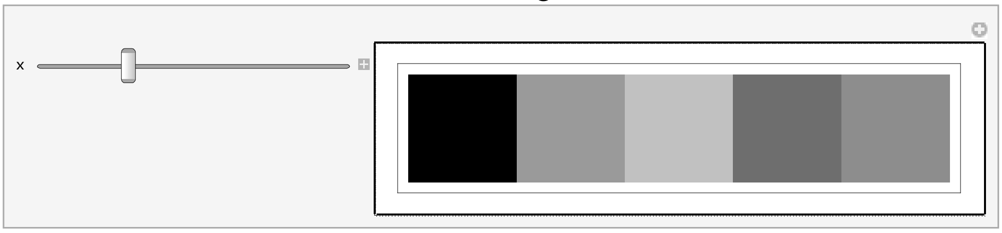
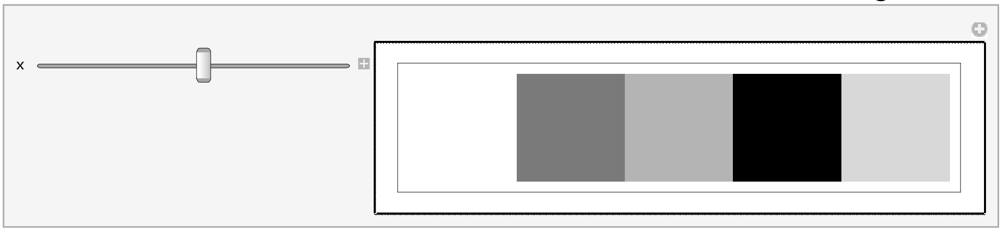


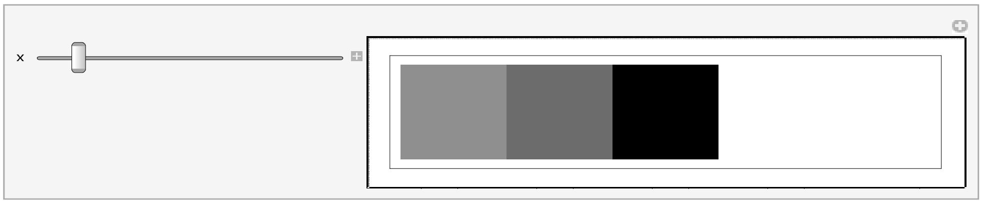
Figure 6: In resource dependent settlements, the synergistic mechanism from c_2 and c_3 costs causes a cost distribution with no cost in migration



In another hypothetical case study, we assume a situation where a cost associated to factor 5 (energy, water, other resources) incurs in riverine coastal steeplands. Our model predicts that, after the action of the synergistic impact mechanism, the final cost distribution includes costs for factors 1, 2 and 3. All the other costs are extinguished. The position of the structural matrix elements is guaranteed, when varying index x in the interval of its possible values we continue to have the same visual scheme.

In the next computer output, we can examine any possible cost scenario that assumes individual or simultaneous costs associated to certain climate change related factors, in riverine coastal steeplands. Each sliding bar controls the value of each c_i and thus, allows the interactive manipulation of the primary and the final cost distribution. c_i is defined as a 0-1 variable, interpreting the unit value as the existence and the zero value as the absence of the corresponding cost. The (0, 0, 1, 0, 0) vector stands for a situation, where, only c_3 cost incurs, due to air and water pollution (Figure 8). The (0, 0, 1, 0, 1) vector states that air - water pollution cost and energy-water-other resources cost co-exist in the primary cost distribution (Figure 9).

Figure 7: In riverine coastal steeplands, the synergistic mechanism from c_5 cost causes a cost distribution with no cost in human health and in energy, water, other resources



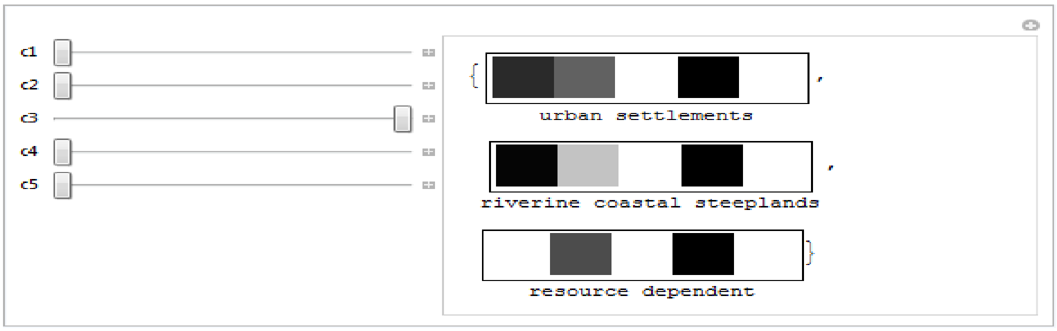
By setting 0-1 values in c_i parameters, the synthesis of the direct cost distribution is defined and, automatically the new developing cost distribution is visualized by a series of grey-shaded squares.

Figure 8: In riverine coastal steeplands, c_3 cost triggers a cost distribution consisting of c_1 c_2 c_4 costs

Figure 9: In riverine coastal steeplands, the co-existence of factors 3 and 5 and their dedicated costs triggers a cost distribution consisting of c_1 c_2 c_3 c_4 costs

Similar cost scenarios could be used in models for any of the three types of settlements, by using the analogous matrix of synergistic cost effects.[45] The generality of the results is assured by making infinite parameters' substitutions with random numbers. An analogous computational framework could be considered to examine cost scenarios with different types of industries.

Figure 10: A comparative output



3.1.2 Potential for a Quantitative Study with Cost Scenarios

Our computer codes aim to derive indicative estimates of the potential costs, assuming any possible direct cost scenario. The direct cost scenario is defined using sliding bars that assign values to each cost from a predefined interval (e.g. [0, 10000]). In Figures 11

[45] The computer codes in *Mathematica* are available on request.

and 12, we examine how similar direct cost distributions end-up differently in urban and resource dependent settlements, due to the synergistic impact mechanisms. In the output produced the user has also the option to perform sensitivity analysis: moving the sliding bars, the primary cost distribution is perturbed and one can observe the variations of the costs computed in the list on the right part of the window.

Figure 11: In urban settlements, costs in migration and flooding pass to all categories of costs.

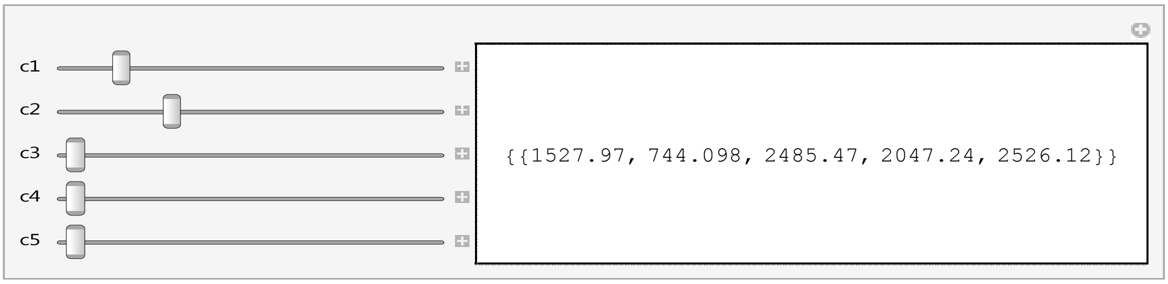
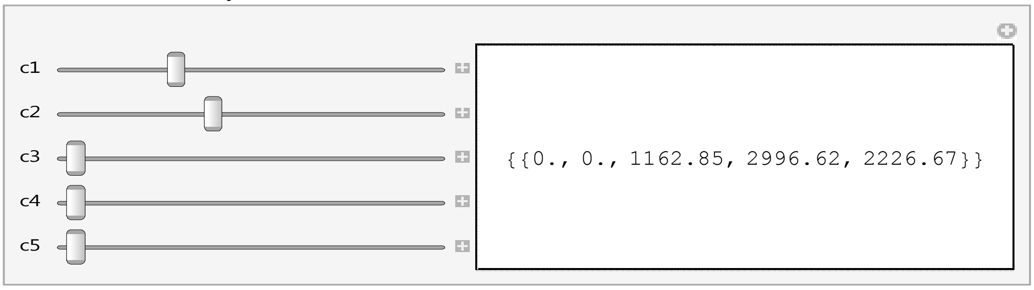


Figure 12: In resource dependent settlements, costs in migration and flooding are extinguished since in the cost variable vector, migration and flooding have steadily zero values.



3.2 Nonlinear Interactions of climate related costs

In the case when climate related costs interact with each other in a nonlinear fashion, the matrix of synergistic cost effects should contain cells with mathematical functions. That is

$$\begin{pmatrix} f_{11} & f_{12} & f_{13} & f_{14} & f_{15} \\ f_{21} & f_{22} & f_{23} & f_{24} & f_{25} \\ f_{31} & f_{32} & f_{33} & f_{34} & f_{35} \\ f_{41} & f_{42} & f_{43} & f_{44} & f_{45} \\ f_{51} & f_{52} & f_{53} & f_{54} & f_{55} \end{pmatrix}$$

Then, our computational approach generates a functional matrix, where f_{ij} functions could be the regression fits estimated from empirical data for every pair of factors (e.g. 25-7 pairs for urban settlements). The nonlinear functions f_{ij} can be specified by nonlinear regression methods.[46] By setting numerical values in the primary costs (m,f,a,h,e), our codes compute the costs after the impact of synergistic mechanism. The sum of each column will give the cost of the corresponding climate related factor.

The *Mathematica* codes for modeling the nonlinear synergistic mechanism and for automatic calculation of costs are presented next. That is:

```
a[i_, j_] := Which[i == 1 && j == 1, 0, i == 1 && j == 2, f12[m], i == 1 && j == 3, f13[m], i == 1 && j == 4, f14[m], i == 1 && j == 5, f15[m],
  i == 2 && j == 1, f21[f], i == 2 && j == 2, 0, i == 2 && j == 3, f23[f], i == 2 && j == 4, f24[f], i == 2 && j == 5, f25[f],
  i == 3 && j == 1, f31[a], i == 3 && j == 2, f32[a], i == 3 && j == 3, 0, i == 3 && j == 4, f34[a], i == 3 && j == 5, 0,
  i == 4 && j == 1, f41[h], i == 4 && j == 2, f42[h], i == 4 && j == 3, f43[h], i == 4 && j == 4, 0, i == 4 && j == 5, f45[h],
  i == 5 && j == 1, f51[e], i == 5 && j == 2, f52[e], i == 5 && j == 3, f53[e], i == 5 && j == 4, 0, i == 5 && j == 5, 0]

Table[a[i, j], {i, 5}, {j, 5}] // MatrixForm
```

$$\begin{pmatrix} 0 & f12[m] & f13[m] & f14[m] & f15[m] \\ f21[f] & 0 & f23[f] & f24[f] & f25[f] \\ f31[a] & f32[a] & 0 & f34[a] & 0 \\ f41[h] & f42[h] & f43[h] & 0 & f45[h] \\ f51[e] & f52[e] & f53[e] & 0 & 0 \end{pmatrix}$$

4. Potential data sources for empirical applications

Some directions for valuation of climate impacts and appropriate metrics are given in IPCC (2001, par. 7.3.6). Methods and tools for costing impacts and adaptation of extreme events and disasters are analyzed in par. 4.5 of the special report by IPCC (IPCC, 2012a). Economic impacts of climate change are discussed in the report by the European Commission (SWD, 2013).

When studying more factors related to climate change than the ones examined in this paper, the first step is to test the existence of any causal relationships (one way, both ways or irrelevant) using econometric tests like Granger causality test. The methodology to estimate the entries in the matrices of synergistic effects of section 3 is related to statistical methodologies available for the investigation and estimation of cost interactions like correlation or regression analyses.[47]

Empirical applications of the proposed model formulations demand data for appropriate estimates of the primary costs of the five climate related factors under investigation. In the case of Greece and using the settlement and industry types mentioned so far, various databases can be used. Some indicative preliminary guidance (depending on data availability in regional or local level) follows. Specifically:

1. Migration costs can be approximated by the absolute[48] value of the annual population variation (source: http://data.worldbank.org) multiplied by the GDP per capita of the relevant year (source: http://data.worldbank.org). Alternatively various percentages may be assured for the contribution of emigrants and immigrants to GDP.
2. Flooding-landslides-fires costs can be approximated by the compensations due to extreme weather events, available from the General Secretariat for Civil Protection (http://www.gscp.gr/ggpp/site/home/ws.csp)

[46] Nonlinear regression analysis is performed with observations modeled by a nonlinear combination of model's parameters either in a bivariate or a multiple regression specification (Seber and Wild, 1989).
[47] Exploring the issues of synergistic impacts of climate related costs it is important to be clear in the distinction between correlation and causation.
[48] Taking into consideration only the costs associated with migration.

3. Air Pollution costs can be approximated by multiplying annual CO_2 emissions (kt) (source: http://data.worldbank.org) with the mean value of the allowance price evolution in the EU ETS for a specific time period like 2005-2009[49] or 2009-2013 etc (source: http://www.theccc.org.uk/publication/meeting-carbon-budgets-the-need-for-a-step-change-1st-progress-report/)
4. Human Health costs can be approximated by hospitalization costs of the very young (i.e. <1 year of age), older adults (i.e. those of ≥65 years of age) and immunocompromised individuals, available by the Hellenic Statistical Authority (http://www.statistics.gr). As Ebi et al. (2006) and Mills (2009) claim these three groups are usually the most sensitive and at the highest risk in terms of health outcomes due to climate conditions as they are quite sensitive to food- and water-borne diseases, present limited capacity to adapt to extreme temperatures and have less ability to cope properly with behavioral changes when they face these extreme temperatures and extreme weather conditions.
5. In the case of access to energy, clean water and other resources we may limit for simplicity to energy costs, which can be approximated by multiplying annual energy use (kt of oil equivalent) (source: http://data.worldbank.org) with oil prices of the relevant year (source: http://ec.europa.eu/energy/observatory/oil/prices_en.htm)

5. Conclusions

Climate related costs are linked through interactions estimated by appropriate impact indicators. Our contribution provides constructs of the matrix with these impact indicators, aiming to represent its structure and trying to define its entries. In a second step, we make matrix economic system models for human settlements and types of industries, to evaluate the costs related to the synergistic environmental effects.

Our proposed models could help decision makers to obtain either the synthesis or the numerical estimate of cost distribution variable vector. To illustrate the results, we build interactive applications in *Mathematica*; we provide instant creation of dynamic interfaces that allow varying parameters and gaining useful insights from datasets. Our computational approach provides a parameter setting for the existence of costs, the amount of costs and the impact indicators of costs. Varying parameters' values, each case study concerning human settlements or industries is examined in a stochastic fashion. The variety and the clarity of the computer output are the models' advantages.

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Investors' Reactions to Natural and Anthropogenic Adversity

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Abstract
It is widely claimed that climate change has increased the magnitude and the frequency of natural phenomena such as storms, droughts and floods with the concomitant costs in terms of damages and victims. This paper using monthly data from European stock market indices in an asset pricing framework, examines how and to what extent market agents and investors react to such events. As a yardstick for comparison purposes, the possible market impact of industrial accidents is also incorporated and examined in the empirical investigation. The study focuses on a specific group of sustainability indices, including Environmental, Social and Governance leader stock indices. Results reported herein seem to indicate that major adverse natural events as well as industrial accidents exert a significant effect on returns and other risk factors in a Fama-French model with significant implications for investors' behavior.

Keywords: Socially responsible investments; behavioural finance; natural disasters.

JEL Classification: G10, G14, Q54

1. Introduction

Climate change and in particular human induced environmental degradation are issues that invariably rank high in the international agenda and discourse (*inter alia*: Goudie, 2000; Maler and Vincent, 2003, 2005a, 2005b; Halkos 2003, 2013; Halkos and Tzeremes, 2013a, 2013b). The need to adopt an economic and production paradigm that bears less weight on the fragile environment and eventually leads to a more sustainable symbiosis between the latter and human activities, is exerting an appreciable influence both on public policies as well as the choices and behavior of private economic agents (*inter alia*: Crifo and Forget, 2014; Erdogan, 2013; Oates and Portney, 2003; Perman, 1994; Heal and Kristrom, 2005; Xepapadeas, 2005; Bolin, 2003). Facets of this increasing concern over environmental issues are present in all aspects of economic activity, spanning all sectors of the economy. As, among others, Climent and Soriano (2011) observe, the increased concern that societies and individuals show with respect to the environmental effects caused by economic activity, has led to the growth of investment opportunities in funds with portfolios that specialize in investing in assets and companies that adopt and implement environmental responsibility (*inter alia*: Statman, 2000; Sabbaghi, 2010; King and Lenox, 2001).

Indeed, as Chang *et al*. (2012) note, this trend in professional asset management is towards adopting investment policies and strategies that incorporate in a prominent and often decisive manner environmental, social and governance parameters when examining investment opportunities and selecting stocks and shares for their portfolio. Such funds, that fall under the broad category of socially responsible, are by no means new as noted by Climent and Soriano (2011). But they have grown in numbers in the past few years very much as markets' response to the general public's increased concern, sensitivity and awareness over such issues (*inter alia*: Renneboog *et al*. 2008; Statman, 2000). This, as already noted, is particularly true for mutual funds that offer environmentally responsible investment opportunities given that investor demand for portfolios that specialize in green investments such as for instance energy produced from renewable sources, green technology, property development that adopts green standards and materials, has steadily grown.

This demand growth may not necessarily be driven solely by environmental principles but simply by the prospects of safer investment opportunities or the prospects of comparatively higher returns. Nevertheless, as a study by Holm and Rikhardsson (2006) shows, environmental information exerts an influence on investment allocation decisions which however are mitigated by other investment parameters such as the time horizon of the investment. Not surprisingly, the performance of investment portfolios and mutual funds that fall in the broader category of funds observing environmental, social responsibility and governance rules has in recent years come under empirical scrutiny by a number of studies, examining whether vis-à-vis more traditional mainstream investment options and opportunities, environmentally sensitive portfolios exhibit higher returns and/or lower risks. The evidence is by no means conclusive (*inter alia*: Statman, 2000; Sabbaghi, 2010; Munoz *et al*. 2013; King and Lenox, 2001).

Particular attention on systematic risk of environmental friendly investments has been paid in two studies. Ramiah et al (2013) indicate that 19 announcements of environmental regulation may affect not only returns but also systematic risk of stock sectors. However, the result differs across sectors depending on the company actions concerning environmental issues. Moreover, Halkos and Sepetis (2007) in case of Greek companies found that improved environmental management system and environmental performance result in reductions in firms' beta.

In the broader spirit of such studies, this paper using monthly data from global social responsible stock indices in an asset pricing framework, examines how and to what extent market agents and investors react to environmental issues as these are brought to the forefront of public discourse and debate as a result of major, headline catching climatic events such as storms, droughts and floods with the concomitant costs in terms of damages and victims. It is widely claimed that climate change has increased the magnitude and the frequency of such natural phenomena. Hence, their occurrence fuels discussion and concerns over the impact anthropogenic activity bears on the environment. In turn, such increased attention may act as an impetus that drives investors towards mutual funds that offer green investment opportunities. As numerous studies have shown, calamitous events, natural or anthropogenic, apart from the loss of life and human suffering have serious economic ramifications in the form of both direct and indirect private and social costs to market and non-market goods and services, including cleaning and restoration, property losses, damages to economic-productive activities and income (*inter alia*: Kaplanski and Levy, 2010 ; Garza, *et al*. 2009; Loureiro *et al*. 2009; Noy, 2009; Suris-Regueiro et al. 2007; Al-Nammari and Lindell, 2008; Butler and Doessel, 1980).

They can also affect markets through risk premia and investors' sentiment affecting asset valuation, investment decisions and portfolio allocation. For our purposes here, such events are used to examine whether or not they affect the performance of stock market indices that are constructed of stocks of companies that observe environmental, social responsibility and governance principles. In particular, three such indices are used: Environmental stock index (GEP), Social stock index (GSP) and Governance stock index (GGP). The companies' stocks used for their construction are selected on the basis of specific criteria fulfilment for each of the three categories, i.e. Environment, Society, and Governance. Such indices are often referred to as sustainability indices in order to distinguish them from the more traditional market indices. In particular, we examine whether major calamitous natural events such as floods, extreme temperature, wildfires exert an impact on these three indices. The intuition being that natural mega-disasters draw the spotlight of international media attention and hence augment, even temporarily, public opinion interest on environmental issues. This is turn may affect investors' decisions and portfolio allocation perhaps in favour of such investment opportunities as the ones offered by the companies included in the three indices.

2. Data and Methodology

In order to address the issue at hand a number of extreme natural events are selected. The source for these events as well as their attributes is EM-DAT, an international disasters database that groups major calamitous distinguishes into two generic disaster categories: natural and technological. The former is divided into 5 sub-groups, which in turn cover 12 disaster types and more than 30 sub-types[50]. For a disaster to be entered into the database at least one of the following criteria must be fulfilled: a) ten (10) or more people reported killed; b) hundred (100) or more people reported affected; c) declaration of a state of emergency; d) call for international assistance.

For the purposes of the empirical analysis that follows we focus on climatological and hydrological disasters. Moreover, as noted earlier, industrial accidents, that are part of the technological disasters category, are also selected and used as a benchmark to compare and contrast possible differences in investors' reactions in the case of natural and anthropogenic calamity. The general classification of the disasters based on EM-DAT database is shown in table 1, while the shaded cells indicate the primary focus of this study. In particular, the type of events analyzed can be grouped into five categories: a) extreme temperature events; b) storms; c) floods; d) wildfires; e) industrial accidents. The selection criteria applied are simple and straightforward: the three biggest events in each continent in economic terms are selected from the EM-DAT database. Their attributes in terms of location, occurrence date, damages, victims and costs are shown in Tables 2a to 2e.

[50] For technical and methodological details of these divisions, classifications and groupings see http://www.emdat.be/

Table 1: Natural versus Technological disasters

Main Disaster Groups	Disaster Subgroup	Definition	Disaster Main Type	Disaster Sub-Type	Disaster Sub-sub Type
Natural Disasters	Geophysical	Events originating from solid earth	Earthquake,		
			Volcano,		
			Mass Movement (dry)		
	Meteorological	Events caused by short-lived/small to meso scale atmospheric processes (in the spectrum from minutes to days)	Storm	Tropical Storm, Extra-Tropical cyclone (winter strom)	
				Local / Convective Storm	Thunderstorm /Lightening, Snowstorm/Blizzard, Sandstorm / Dust storm, Generic (severe) Storm,Tornado, Orographic (Strong winds)
	Hydrological	Events caused by deviations in the normal water cycle and/or overflow of bodies of water caused by wind set-up	Flood	General, river flood, Storm surge / coastal flood	
	Climatological	Events caused by long-lived/meso to macro scale processes (in the spectrum from intra-seasonal to multi-decadal climate variability)	Extreme Temperature	Heat Wave	
				Cold Wave	Frost
				Extreme Winter Conditions	Snow, Pressure, Icing, Freecing Rain Debris avalanche
			Wildfire	Forest Fire, Land fires (grass, scrub, bush, etc.)	
	Biological	Disaster caused by the exposure of living organisms to germs and toxic substances	Epidemic,		
			Insect infestation,		
			Animal Stampede		
Technological Disaster	Industrial Accident	Disaster type term used in EM-DAT to describe technological accidents of an industrial nature/involving industrial buildings (e.g. factories).	Collapse, Explosion, Fire, Gas Leak, Other		
	Miscellaneous Accident	Disaster type term used in EM-DAT to describe technological accidents of a non-industrial or transport nature (e.g. houses)			
	Transport Accident	Disaster type term used in EM-DAT to describe technological transport accidents involving mechanised modes of transport. It comprises of four disaster subsets: accidents involving aeroplanes, helicopters, airships and balloons « Transport:Air »; accidents involving sailing boats, ferries, cruise ships, other boats « Transport:Boat »; accidents involving trains « Transport:Rail »; and accidents involving motor vehicles on roads and tracks « Transport:Road			

Source: http://www.emdat.be/

Table 2a: Details about major extreme temperatures disasters

	Dates		Geography		Disaster			Numbers		
	Start	End	Country	Location	Type	Sub Type	Name	Killed	Tot. Affected	Est. Damage (US$ Million)
Europe	16/07/2003	15/08/2003	Italy	Milan, Turin	Extreme temperature	Heat wave		20089		4,400
	01/08/2003	20/08/2003	France	Paris region - all country	Extreme temperature	Heat wave		19490		4,400
	00/08/2003	00/08/2003	Germany		Extreme temperature	Heat wave		9355		1,650
	00/01/2006	00/01/2006	Russia	Moscow, Volgograd region	Extreme temperature	Extreme winter conditions		116	14	1,000
America	26/01/2009	28/01/2009	United States	Texas, Pennsylvania, Oklahoma	Extreme temperature	Cold wave		58		1,100
	01/02/2011	08/02/2011	Mexico	Sinaloa, Sonora	Extreme temperature	Cold wave		3	120,000	500
Asia	10/01/2008	05/02/2008	China P Rep	Zhejiang, Sichuan, Anhui	Extreme temperature	Extreme winter conditions		129	77,000,000	21,100
	00/01/2008	00/02/2008	Tajikistan	Khatlon'Panj	Extreme temperature	Extreme winter conditions			2,000,000	840
	14/05/2003	06/06/2003	India	Andhra Pradesh, Orissa	Extreme temperature	Heat wave		1210		400

Source: http://www.emdat.be/

Table 2b: Details about major storms

	Dates		Geography		Disaster			Numbers		
	Start	End	Country	Location	Type	Sub Type	Name	Killed	Tot. Affected	Est. Damage (US$ Million)
Europe	18/01/2007	18/01/2007	Germany		Storm	Extratropical cyclone	Kyrill	11	130	5,500
	28/02/2010	02/03/2010	France	Charente-Maritime	Storm	Extratropical cyclone (winter storm)	Xynthia	53	500,079	4,230
	23/01/2009	26/01/2009	France	Landes, Pyrinies	Storm	Extratropical cyclone (winter storm)	Klaus	11		3,200
America	29/08/2005	19/09/2005	United States	Mobile, Bayou La Batre	Storm	Tropical cyclone	Katrina	1833	500,000	125,000
	28/10/2012	28/10/2012	United States	New York, New Jersey	Storm	Tropical cyclone	Hurricane Sandy	54		50,000
	12/09/2008	16/09/2008	United States	Galveston, Brazoria	Storm	Tropical cyclone	Hurricane Ike	82	200,000	30,000
Asia	03/09/2004	04/09/2004	Japan	Kyushu Isl.	Storm	Tropical cyclone	Songda (Nina/22W)	41	40,900	9,000
	12/09/2003	12/09/2003	Korea Rep	Gyeongsang, Gangweon	Storm	Tropical cyclone	Maemi	130	80,000	4,500
	31/08/2002	06/09/2002	Korea Rep	Gyeongsang, Chulan Chungci	Storm	Tropical cyclone	Rusa	184	88,625	4,200
Australia	02/02/2011	05/02/2011	Australia	Cassowary Coast Shire	Storm	Tropical cyclone	Tropical Cyclone 'Yasi'	1	7,300	2,500
	23/01/2013	30/01/2013	Australia	Brisbane, Ipswich	Storm	Tropical cyclone	Ex-Tropical cyclone Oswald	6	7,500	2,000
	22/03/2010	22/03/2010	Australia	Joondalup, Mandurah	Storm	Local storm				1,390

Source: http://www.emdat.be/

Table 2c: Details about major flood disasters

	Dates		Geography		Disaster			Numbers		
	Start	End	Country	Location	Type	Sub Type	Name	Killed	Tot. Affected	Est. Damage (US$ Million)
Europe	11/08/2002	20/08/2002	Germany	Basse-Saxe, Saxe-Anhalt	Flood			27	330,108	11,600
	20/07/2007	24/07/2007	United Kingdom	Gloucestershire	Flood	General flood		7	340,000	4,000
	25/06/2007	03/07/2007	United Kingdom	Yorkshire, Lincolnshire	Flood	General flood		6	30,000	4,000
	17/05/2010	26/05/2010	Poland	Cracovie, Vrasovie	Flood	General Flood		16	100,000	3,080
America	09/06/2008	30/06/2008	United States	Illlinois, Iowa, Kansas	Flood	General Flood		24	11,000,148	10,000
	18/04/2011	23/05/2011	United States	Mississippi valley, Ohio	Flood	General Flood		9		4,600
	28/10/2007	16/11/2007	Mexico	Chiapas, Tabasco	Flood	General flood		22	1,600,000	3,000
	20/06/2013	27/06/2013	Canada	Southern Alberta, Calgary	Flood	General Flood		3	100,000	3,000
Asia	05/08/2011	04/01/2012	Thailand	Phrae, Mae Hong Son	Flood	General Flood		813	9,500,000	40,000
	29/05/2010	31/08/2010	China P Rep	Fujian, Sichuan, Guangxi	Flood	General Flood		1691	134,000,000	18,000
	28/07/2010	07/08/2010	Pakistan	Khyber Pakhtunkhwa	Flood	Flash Flood		1985	20,359,496	9,500
	21/07/2012	24/07/2012	China P Rep	Beijing	Flood	General Flood		151	1,000,000	8,000
Australia	25/12/2010	04/02/2011	Australia	Queensland, New South Wales	Flood	General Flood		35	175,000	7,300
	08/06/2007	12/06/2007	Australia	Central Coast, Hunter	Flood	Flash flood		9	5,000	1,300
	13/02/2008	26/02/2008	Australia	Mackay (Queensland)	Flood	General Flood		2	1,000	1,100

Source: http://www.emdat.be/

The sample period extends from January 2000 to December 2013. Monthly data for stock sustainability indices are collected from the stoxx database[51]. The STOXX ESG

[51] www.stoxx.com

Leaders (Environment, Society, and Governance) indices are sustainability indices based on a fully transparent and rule-based selection process. Sustainalytics, a leading global provider of ESG research and analysis, provides key performance indicators (KPIs) to construct a relative rating using a fully transparent weighting model. The set of indicators which underlies the environmental, social and governance criteria follows the Key Performance Indicators for ESG 3.0 outlined by DVFA[52].

Table 2d: Details about major wildfires

	Dates		Geography		Disaster			Numbers		
	Start	End	Country	Location	Type	Sub Type	Name	Killed	Tot. Affected	Est. Damage (US$ Million)
Europe	18/07/2005	18/07/2005	Spain	Near Guadalajara	Wildfire	Forest fire		11	1	2,050
	00/07/2010	06/08/2010	Russia	Nizhniy Novgorod, Riazan	Wildfire	Bush/Brush fire		53	5,996	1,800
	24/08/2007	30/08/2007	Greece	Messinie, Laconie (Peloponese)	Wildfire	Forest fire		67	5,392	1,750
America	21/10/2003	04/11/2003	United States	San Bernardino (California)	Wildfire	Forest fire		4	40	3,500
	21/10/2007	24/10/2007	United States	Los Angeles, Orange	Wildfire	Scrub/grassland fire		8	640,064	2,500
	13/11/2008	18/11/2008	United States	Los Angeles, Orange	Wildfire				55,020	2,000
Asia	02/12/2010	05/12/2010	Israel	Carmel forest	Wildfire	Forest fire		44	20,022	270
	00/08/2006	00/08/2006	Indonesia	Muaro Jambi	Wildfire	Forest fire			200	14
Australia	02/02/2009	14/02/2009	Australia	Matysville, Kinglake	Wildfire	Bush/Brush fire		180	9,954	1,300
	08/01/2003	18/02/2003	Australia	Canberra region	Wildfire	Forest fire		4	2,650	300
	25/12/2001	16/01/2002	Australia	Sydney, Canberra	Wildfire	Scrub/grassland fire			4,400	90

Source: http://www.emdat.be/

Table 2e: Details about major industrial accidents

	Dates		Geography		Disaster			Numbers		
	Start	End	Country	Location	Type	Sub Type	Name	Killed	Tot. Affected	Est. Damage (US$ Million)
Europe	17/11/2002	17/11/2002	Spain	Galicia	Industrial Accident	Other			734	9,960
	17/08/2009	17/08/2009	Russia	Khakassia region	Industrial Accident	Collapse	Sayano-Shushenskaya Hydro-electric power plant	75	14	1,320
	11/11/2007	11/11/2007	Ukraine	Kertch detroit (Ukraine)	Industrial Accident	Chemical Spill		6		867
America	20/04/2010	20/04/2010	United States	Mexico Gulf	Industrial Accident	Explosion	Oil plateform 'Deewater Horizon'	11	17	20,000
	23/10/2009	23/10/2009	Puerto Rico	San Juan	Industrial Accident	Explosion	Oils storage facility		1,500	6
Asia	27/07/2005	27/07/2005	India	Moan sea (coast of Mahara)	Industrial Accident	Fire	Petrol plateforme	23	351	410
	29/10/2009	29/10/2009	India	Jaipur (Rajasthan)	Industrial Accident	Explosion	Oil storage depot	11	2,135	200
	27/09/2012	27/09/2012	Korea Rep	Gumi	Industrial Accident	Gas Leak		5	3,178	30

Source: http://www.emdat.be/

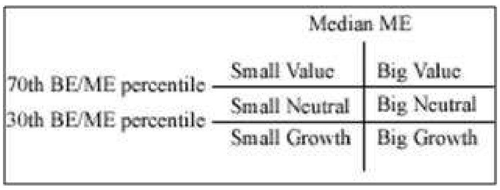
[52] The DVFA is the Society of Investment Professionals in Germany (Deutsche Vereinigung für Finanzanalyse und Asset Management)/ EFFAS (The European Federation of Financial Analysts Societies) see http://www.effas-esg.com/wp-content/uploads/2011/07/KPIs_for_ESG_3_0_Final.pdf.

For example indicators are based on criteria (a) **environmental** such as total energy consumption, total GHG emissions, emissions to Air (Total CO^2,NOx, SOx, VOC emissions in million tonnes); (b) **social** such as percentage of full time employees leaving p.a./total full time employees, average expenses on training per full time employees p.a.; (c) **governance** such as litigation risks (Expenses and fines on filings, law suits related to anti-competitive behavior, anti-trust and monopoly practices), corruption (Percentage of revenues in regions with Transparency International corruption index below 6.0).

We propose to test a number of questions. The first is whether major natural disasters in terms of the economic damages caused exert any effect on stock returns. The second issue that will be examined is whether systematic risk is altered over the duration period of the natural calamity. For the purpose of this analysis an extended version of a Fama-French model is estimated. The standard model is enriched by the inclusion of a set of dummy variables for each type of the natural catastrophes examined here. The constant dummies capture any significant abnormal returns over the month that the event occurred. Additionally, slope dummies relevant to the excess return of the market portfolio to the risk free rate (RM-RF) are also included in the model. This is done in order to investigate any change in systematic risk over the disaster periods under examination. Particular attention is given on any possible differences among the three sustainability indices and a well-diversified across continents Global 1800 index.

The risk factors introduced by Fama and French (1993) are made available by Kenneth French for the whole world on a monthly basis (Global FF factors)[53]. The portfolios, which are constructed at the end of each June, are the intersections of two portfolios formed on size (market equity, ME) and three portfolios formed on the ratio of book equity to market equity (BE/ME). The size breakpoint for year *t* is the median global market equity at the end of June of year *t*. BE/ME for June of year *t* is the book equity for the last fiscal year end in *t-1* divided by ME for December of *t-1*. The BE/ME breakpoints are the 30th and 70th markets percentiles (see table 3). Specifically, the SMB is the average return on the three small-capitalized portfolios minus the average return on the three big-capitalized portfolios [SMB =1/3 (Small Value + Small Neutral + Small Growth) - 1/3 (Big Value + Big Neutral + Big Growth)], whilst HML is the average return on the two value portfolios minus the average return on the two growth portfolios [HML =1/2 (Small Value + Big Value) - 1/2 (Small Growth + Big Growth)].

Figure 1: Construction of the Fama-French Factors



[53] The global factors and portfolios include all 23 countries in the four regions: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hong Kong, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Switzerland, Sweden, United Kingdom, United States. (http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html#Developed).

Following asset pricing theories, the risk return trade-off and previous empirical research (see for instance, Elyasiani and Mansur, 1998; Brewer *et al*., 2007; Elyasiani, *et al*., 2007; Papadamou and Siriopoulos, 2014) a GARCH-in-mean model consisting by equations (1) to (3) is estimated by using maximum likelihood method:

$$R_{i,t} - RF_t = \beta_{i,0} + \beta_{i,1}(RM_t - RF_t) + \beta_{i,2}SMB_t + \beta_{i,3}HML_t + \sum_{j=1}^{5}\beta_{i,4,j}D_{j,t}(RM_t - RF_t) + \sum_{j=1}^{5}\beta_{i,5,j}D_{j,t} + \gamma\sqrt{(h_t)} + u_t \quad (1)$$

$$u_t \mid \Omega_{t-1} = \sqrt{h_t}\cdot z_t \qquad z_t \sim iid\ N(0,1) \quad (2)$$

$$h_t = a_0 + a_1 u_{t-1}^2 + a_2 h_{t-1} \quad (3)$$

Where $R_{i,t}$ is the return on the i (where i=GEP for the Environment Index, GSP for the Society Index, GGP for the Governance Index) stock index in month *t*; RM_t is the return on the market portfolio in *t*; RF is the risk free rate proxied by three month Euribor; L is a dummy for the announcement of the Lehman Brothers default that takes the value of one for September 2008 and zero elsewhere. By allowing exogenous shifts in stock returns from the natural disaster events, dummy variables D_j, taking the value of one over the month of the *j* event (where j=1 Extreme Temperature, j=2 Storm, j=3 Flood, j=4 Fire, j=5 Industrial accident) and zero otherwise, are used. If all D_j=0, the mean return of the i index is measured by the $\beta_{i,0}$ coefficient while the coefficient measuring the systematic risk is $\beta_{i,1}$. Otherwise and depending on the type of the disaster occurred in time mean return and systematic risk may be altered.

The volatility of stock returns is measured by conditional variance h_t, which is described as a function of the squared values of the past residuals presenting the ARCH factor, and an autoregressive term h_{t-1} reflecting the GARCH character of the model. The coefficients a_1 and a_2 must satisfy the stationarity conditions such that $a_1 \geq 0, a_2 \geq 0$ and $a_1 + a_2 \geq 0$.[54] The degree of volatility persistence is measured by the sum of coefficients a_1 and a_2.

In order to take into account any possible delay in the investor reactions equations (1) is modified by using one time lag of the relevant dummies. Therefore the whole analysis has been conducted also for the following modified model:

$$R_{i,t} - RF_t = \beta_{i,0} + \beta_{i,1}(RM_t - RF_t) + \beta_{i,2}SMB_t + \beta_{i,3}HML_t + \sum_{j=1}^{5}\beta_{i,4,j}D_{j,t-1}(RM_t - RF_t) + \sum_{j=1}^{5}\beta_{i,5,j}D_{j,t-1} + \gamma\sqrt{(h_t)} + u_t \quad (4)$$

$$u_t \mid \Omega_{t-1} = \sqrt{h_t}\cdot z_t \qquad z_t \sim iid\ N(0,1) \quad (5)$$

$$h_t = a_0 + a_1 u_{t-1}^2 + a_2 h_{t-1} \quad (6)$$

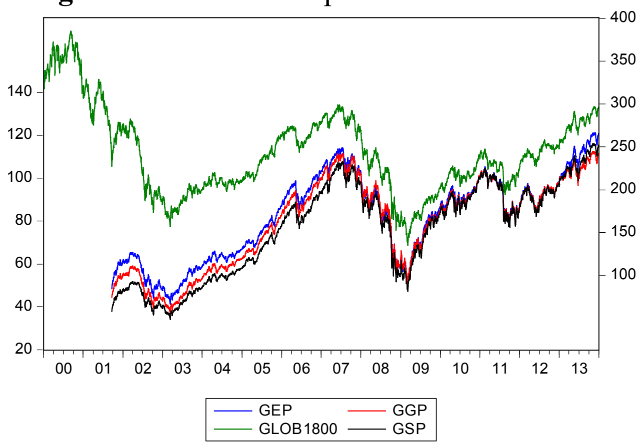
[54] We have to mention at this point that the Engle and Ng (1993) tests for asymmetry in volatility, known as sign and size bias tests provide evidence for a symmetric GARCH in case of stock returns.

3. Empirical Results

As it can be seen from Tables 2a to 2e where the specific attributes of both the anthropogenic as well as natural disaster events are shown, storms exhibit the highest costs in terms of economic damages. Also worth noticing is the significant number of deaths during the extreme temperature conditions in Europe over the period July –August 2003.

Before proceeding with the estimation results of the extended Fama-French model, it is worth looking at the evolution of the three sustainability indices versus the Global 1800 index over the period studied. This is done in Figure 2. As can be seen, the three sustainability indices although they had broadly similar movements, towards the end of the sample period the environmental index outperform the other two.

Figure 2: Evolution of prices for stock indices



The maximum likelihood estimates of the extended with dummies Fama-French model (model 1) in order to uncover the effect of investors' reaction to natural and anthropogenic adversity events are shown in Table 3. In a final version the FF model extended with only the statistically significant explanatory variables is presented (model 2). On the one hand, in order to see the performance (risk and return) of equity indices on the occurrence of a particular disaster event, investors' reaction during that month of the specific *j* event is analysed. To this effect, a relevant constant dummy and a slope dummy referred to as market risk factor are included in the model. The later, may capture any significant change in systematic risk.

The empirical findings reported in table 3 point to a positive effect on the three sustainability indices returns only in periods of industrial accidents (almost 2% increase in all three cases ESG). This finding provides evidence that suggests that anthropogenic calamities spur a flow towards more social responsible investments. This assertion is strengthened by the fact that no significant return was present in case of the global investment strategy. Another interesting finding is the negative reaction of investors in case of wildfires for all indices.

Table 3: Maximum Likelihood estimation results in case of an immediate effect of natural and anthropogenic adversity on stock returns

		GEP Index				GSP Index				GGP Index				Global 1800 Index			
Mean Equation modified FF:		$R_{i,t} - RF_t = \beta_{i,0} + \beta_{i,1}(RM_t - RF_t) + \beta_{i,2}SMB_t + \beta_{i,3}HML_t + \sum_{j=1}^{5}\beta_{i,4,j}D_{j,t}(RM_t - RF_t) + \sum_{j=1}^{5}\beta_{i,5,j}D_{j,t} + \gamma\sqrt{(h_t)} + u_t$															
		Model 1		Model 2		Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
Coef.	**Variables**	Coef.	Prob.	Coef.	Prob.	Coef.	Prob.	Coef.	Prob.	Coef.	Prob.	Coef.	Prob.	Coef.	Prob.	Coef.	Prob.
γ	$h_t^{0.5}$	0.299	(0.64)	0.476	(0.45)	-0.173	(0.70)	0.046	(0.92)	0.379	(0.61)	0.482	(0.45)	-0.455	(0.22)	-0.259	(0.44)
β_0	Intercept	-0.002	(0.88)	-0.007	(0.69)	0.009	(0.43)	0.004	(0.79)	-0.004	(0.83)	-0.006	(0.70)	0.014	(0.20)	0.009	(0.36)
β_1	RM_t-RF_t	0.575	(0.00)***	0.592	(0.00)***	0.584	(0.00)***	0.612	(0.00)***	0.651	(0.00)***	0.672	(0.00)***	0.483	(0.00)***	0.482	(0.00)***
β_2	SMB_t	0.934	(0.00)***	0.944	(0.00)***	0.992	(0.00)***	1.041	(0.00)***	1.022	(0.00)***	1.031	(0.00)***	0.528	(0.00)***	0.486	(0.00)***
β_3	HML_t	-0.230	(0.09)*	-0.237	(0.08)*	-0.204	(0.09)*	-0.209	(0.09)*	-0.216	(0.11)	-0.197	(0.14)	-0.137	(0.37)	-0.177	(0.21)
$\beta_{4,1}$	$D_{1,t}$ (ExT)*(RM_t-RF_t)	0.389	(0.04)**	0.376	(0.02)**	0.237	(0.23)			0.240	(0.15)			-0.054	(0.85)		
$\beta_{4,2}$	$D_{2,t}$ (St)*(RM_t-RF_t)	-0.068	(0.66)			-0.076	(0.63)			-0.135	(0.37)			-0.019	(0.91)		
$\beta_{4,3}$	$D_{3,t}$ (Fl)*(RM_t-RF_t)	0.172	(0.18)			0.206	(0.06)			0.162	(0.19)			0.062	(0.70)		
$\beta_{4,4}$	$D_{4,t}$ (Fire)*(RM_t-RF_t)	-0.153	(0.32)			-0.191	(0.21)			-0.140	(0.39)			-0.260	(0.12)		
$\beta_{4,5}$	$D_{5,t}$ (Ind)*(RM_t-RF_t)	0.446	(0.04)**	0.397	(0.06)*	0.363	(0.06)*	0.266	(0.18)	0.306	(0.12)			0.430	(0.19)		
$\beta_{5,1}$	$D_{1,t}$ (ExT)	0.001	(0.95)			0.004	(0.65)			0.001	(0.90)			-0.011	(0.23)		
$\beta_{5,2}$	$D_{2,t}$ (St)	0.004	(0.51)			0.003	(0.54)			0.002	(0.70)			0.010	(0.02)**	0.009	(0.04)**
$\beta_{5,3}$	$D_{3,t}$ (Fl)	0.006	(0.28)			0.006	(0.25)			0.007	(0.18)			0.010	(0.19)		
$\beta_{5,4}$	$D_{4,t}$ (Fire)	-0.016	(0.01)**	-0.014	(0.03)**	-0.008	(0.15)			-0.012	(0.04)**	-0.011	(0.10)	-0.014	(0.04)**	-0.012	(0.08)*
$\beta_{5,5}$	$D_{5,t}$ (Ind)	0.019	(0.00)***	0.018	(0.00)***	0.021	(0.00)***	0.017	(0.01)**	0.021	(0.00)***	0.020	(0.00)***	0.009	(0.40)		
Variance Equation:		$h_t = a_0 + a_1 u_{t-1}^2 + a_2 h_{t-1}$															
α_0	Vol. Intercept	2.0E-04	(0.12)	1.7E-04	(0.12)	2.2E-04	(0.13)	1.7E-04	(0.19)	1.6E-04	(0.10)	1.3E-04	(0.12)	5.3E-05	(0.20)	4.6E-05	(0.24)
α_1	ARCH	0.186	(0.06)*	0.156	(0.07)*	0.257	(0.03)**	0.171	(0.04)**	0.152	(0.07)*	0.128	(0.09)*	0.124	(0.04)*	0.120	(0.06)*
α_2	GARCH	0.547	(0.01)**	0.612	(0.00)***	0.455	(0.09)*	0.602	(0.00)***	0.626	(0.00)***	0.691	(0.00)***	0.821	(0.00)***	0.833	(0.00)***
Diagnostics																	
Adjusted R-squared		53%		55%		54%		57%		57%		58%		34%		35%	
Log likelihood		321.855		320.283		324.005		320.727		323.046		319.940		345.970		343.452	
Q(12)			(0.64)		(0.63)		(0.61)		(0.44)		(0.67)		(0.61)		(0.54)		(0.59)
Qsq(12)			(0.96)		(0.94)		(0.95)		(0.75)		(0.91)		(0.82)		(0.74)		(0.62)
ARCH(1)			(0.61)		(0.79)		(0.67)		(0.82)		(0.95)		(0.77)		(0.61)		(0.79)

Notes: ***,**,* indicate statistical significance at 1%,5% and 10% level.

Given the monthly frequency of the data series, the effect of an event that occurred at or near the end of one month may not be fully reflected on average monthly prices. This can be remedied with the introduction of time lags in the dummies. Furthermore, as behavioral finance theory suggests, market participants tend to adjust slowly to the arrival of new information due to inertia and conservatism bias. This leads to delayed interactions and adjustment. A dimension that can also be captured through the use of time lags. To that end Eq. (4 and 6) are estimated and the results are reported in Table 4 where a significant reduction in systematic risk over the month following wildfire events is detected but only in the case of the three sustainability indices. This result implies that investors can benefit by diversifying their portfolios using these sustainability indices. In other words, in the next month of the occurrence of these two specific events the correlation of these indices returns to market returns is reduced significantly. Investors mainly affected by the disasters alter their perception and trading behaviour for these indices

In general from tables 3 and 4, it can be said that the market index coefficient (β_1) is significant, positive, and less than unity for all indices. However, the sustainability indices present a higher systematic and size risk when compared to the Global 1800 index that can be characterised as a more diversified portfolio. Moreover, in the Fama-French model there is evidence for a negative effect of HML portfolio but with weak statistically significance in only some cases. The inclusion of a slope dummy in the case of the market risk factor can potentially price significant changes in the behavior of investors for companies that are characterized as social responsible capturing more complex shifts of the systematic risk.

Any statistical significance in cases of the coefficients of constant dummies assumes direct effect on returns. The constants of these models implies no systematic over performance for sustainability indices in line with Climent and Soriano (2011) in case of US green funds.

Looking at the estimation results for the variance equations in tables 2 and 3, we can conclude that there is evidence of time varying volatility for the indices' returns studied here. The empirical significance of the estimates for the ARCH and GARCH coefficients in the volatility equation is tested using t-tests ($\alpha_1 = 0$, $\alpha_2 = 0$). It appears that volatility persistence is present in all cases providing evidence against traditional models that assume time invariant volatility. The Lehman Brothers default dummy has a significant negative effect which is similar across the stock indices studied. However, the weaker effect is presented in the well diversified global 1800 index again providing evidence for the diversification benefits. The magnitude of the trade-off between the mean and the volatility of stock returns in these indices is determined by the trade-off parameter (γ). However, in all cases this parameter is not being statistically significant, even if in other studies focusing mainly on banks stock returns has been found positive and statistically significant (see for instance Elyasiani & Mansur, 1998).

Table 4: Maximum Likelihood estimation results in case of a delayed effect of natural and anthropogenic adversity on stock returns

		GEP				GSP				GGP				Glob18			
Mean Equation modified FF:	$R_{i,t} - RF_t = \beta_{i,0} + \beta_{i,1}(RM_t - RF_t) + \beta_{i,2}SMB_t + \beta_{i,3}HML_t + \sum_{j=1}^{5}\beta_{i,4,j}D_{j,t-1}(RM_t - RF_t) + \sum_{j=1}^{5}\beta_{i,5,j}D_{j,t-1} + \gamma\sqrt{(h_t)} + u_t$																
		Model 1		Model 2		Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
Coef.	Variables	Coef.	Prob.	Coef.	Prob.	Coef.	Prob.	Coef.	Prob.	Coef.	Prob.	Coef.	Prob.	Coef.	Prob.	Coef.	Prob.
γ	$h_t^{0.5}$	0.397	(0.50)	0.315	(0.61)	0.236	(0.56)	0.184	(0.66)	0.536	(0.30)	0.517	(0.34)	-0.386	(0.37)	-0.314	(0.39)
β_0	Intercept	-0.004	(0.81)	-0.003	(0.87)	4.9E-04	(0.96)	0.001	(0.89)	-0.007	(0.61)	-0.007	(0.65)	0.015	(0.24)	0.012	(0.28)
β_1	RM_t-RF_t	0.747	(0.00)***	0.660	(0.00)***	0.715	(0.00)***	0.668	(0.00)***	0.778	(0.00)***	0.715	(0.00)***	0.524	(0.00)***	0.485	(0.00)***
β_2	SMB_t	0.952	(0.00)***	0.946	(0.00)***	1.031	(0.00)***	1.036	(0.00)***	1.039	(0.00)***	1.041	(0.00)***	0.467	(0.00)***	0.468	(0.00)***
β_3	HML_t	-0.243	(0.09)*	-0.182	(0.09)*	-0.270	(0.03)**	-0.221	(0.08)*	-0.236	(0.10)	-0.210	(0.13)	-0.184	(0.20)	-0.177	(0.21)
$\beta_{4,1}$	$D_{1,t-1}$ (ExT)*(RM_t-RF_t)	0.239	(0.34)			0.187	(0.46)			0.060	(0.80)			-0.117	(0.52)		
$\beta_{4,2}$	$D_{2,t-1}$ (St)*(RM_t-RF_t)	-0.180	(0.33)			-0.046	(0.76)			-0.102	(0.56)			0.056	(0.75)		
$\beta_{4,3}$	$D_{3,t-1}$ (FI)*(RM_t-RF_t)	-0.189	(0.14)			-0.217	(0.11)			-0.208	(0.11)			-0.145	(0.36)		
$\beta_{4,4}$	$D_{4,t-1}$ (Fire)*(RM_t-RF_t)	-0.396	(0.00)***	-0.456	(0.00)***	-0.355	(0.02)**	-0.417	(0.01)**	-0.382	(0.01)**	-0.431	(0.00)***	-0.354	(0.12)		
$\beta_{4,5}$	$D_{5,t-1}$ (Ind)*(RM_t-RF_t)	-0.163	(0.12)			-0.094	(0.40)			-0.149	(0.18)			-0.160	(0.12)		
$\beta_{5,1}$	$D_{1,t-1}$ (ExT)	0.002	(0.89)			0.006	(0.56)			0.002	(0.84)			-0.006	(0.65)		
$\beta_{5,2}$	$D_{2,t-1}$ (St)	-0.003	(0.66)			-0.002	(0.71)			-0.003	(0.59)			-0.009	(0.26)		
$\beta_{5,3}$	$D_{3,t-1}$ (FI)	-0.001	(0.86)			-0.002	(0.72)			-0.001	(0.88)			-0.001	(0.86)		
$\beta_{5,4}$	$D_{4,t-1}$ (Fire)	-0.005	(0.42)			-0.002	(0.74)			-0.003	(0.66)			-0.015	(0.07)*	-0.015	(0.03)**
$\beta_{5,5}$	$D_{5,t-1}$ (Ind)	-0.001	(0.92)			0.004	(0.44)			0.003	(0.66)			0.001	(0.84)		
Variance Equation:	$h_t = a_0 + a_1 u_{t-1}^2 + a_2 h_{t-1}$																
α_0	Vol. Intercept	1.9E-04	(0.17)	1.1E-04	(0.28)	1.7E-04	(0.10)	2.0E-04	(0.07)*	1.6E-04	(0.10)	1.4E-04	(0.11)	4.2E-05	(0.34)	4.4E-05	(0.31)
α_1	ARCH	0.168	(0.11)	0.108	(0.16)	0.243	(0.01)**	0.223	(0.02)**	0.175	(0.04)**	0.148	(0.04)**	0.094	(0.06)*	0.107	(0.06)*
α_2	GARCH	0.584	(0.00)***	0.750	(0.00)***	0.534	(0.00)***	0.517	(0.00)***	0.620	(0.00)***	0.665	(0.00)***	0.859	(0.00)***	0.847	(0.00)***
Diagnostics																	
Adjusted R-squared		54%		56%		55%		58%		57%		59%		37%		37%	
Log likelihood		320.583		318.307		323.984		321.887		321.748		320.043		346.375		343.497	
Q(12)			(0.34)		(0.18)		(0.12)		(0.11)		(0.39)		(0.35)		(0.37)		(0.54)
Qsq(12)			(0.99)		(0.88)		(0.96)		(0.89)		(0.91)		(0.91)		(0.86)		(0.86)
ARCH(1)			(0.87)		(0.68)		(0.99)		(0.93)		(0.66)		(0.86)		(0.71)		(0.64)

Notes: ***,**,* indicate statistical significance at 1%,5% and 10% level.

The last part in all these tables, presents some diagnostics tests on the residuals. It can be easily seen that there is no empirical evidence for autocorrelation and heteroskedasticity across the fitted models. Correlations among explanatory variables and variance inflated factors (VIFs), not provided for reasons of brevity, indicate evidence against any collinearity problem[55]. Moreover, in the last column for each index a final model with the most significant dummies is included to avoid the loss of a significant number of degrees of freedom by keeping all variables into the model. Nevertheless, the

[55] Variance inflation factor measures the level of collinearity between the regressors. It shows how much of the variance of a coefficient estimate of the regressor has been inflated due to collinearity with the other regressors. The estimates of VIFs are available upon request by the authors.

results do not alter in all cases. Looking at the adjusted R^2 measures the lowest value is present in the Fama-French model for Global 1800 index.

4. Conclusions

The paper examined how three sustainability indices react to natural and anthropogenic adversity. A number of mega events in terms of damages were chosen to explore the issue and empirically trace any differences in the reaction. The findings yielded from the estimated models suggest that in the case of specific natural calamities – specifically wildfires – bring about a significant reduction of systematic risk for investment portfolios that follow sustainability strategies as the ones used here, i.e. portfolios that include stocks in companies that meet environmental, social and governance criteria. In this respect the evidence unearthed here suggests that the ESG indices may be an important investment alternative in constructing diversified portfolios and reducing the risk. It is interesting to note that from the various types of disasters this is the case only for wildfires.

A couple of tentative explanations maybe advanced. It is probably plausible to associate this reduction with the fact that forest fires leave a much longer lasting damage imprint on the environment. For a forest to be replenished even with systematic reforestation efforts, decades are required. The damage therefore is of a very long term nature. To this, one must also consider the important role forests play in the reduction of the greenhouse effect. In this context, wildfires probably augment the public's sensitivity over environmental issues and affect investors' behavior and portfolio allocation choices albeit with a time lag which points to a gradual process of change and adjustment as suggested by behavioral finance.

Broadly the same behavioral chain argument may be used to explain that why the results reported herein indicated a significant movement by investors to the sustainability indices in cases of industrial accidents as captured by the positive and statistical significant coefficient in the industrial accident dummy. Industrial accidents invariably cause environmental damages and attract considerable negative publicity. This affects investors' sentiment and portfolio allocation decisions in favor of more environmentally and socially investment choices. However, this flow does not continue over the next month, implying a short lived effect and not a structural change in their investment strategy.

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Nuclear events with their Socio- Environmental effects

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Abstract
The target of this paper is to discuss statistical data for the nuclear events, such as the Chernobyl accident, and the atomic bomb survivors. The corresponding data analysis for data collected for humans, concerns the Sociological part while the physical disasters, concern the Environment effects. The sad Chernobyl nuclear accident has some influence in both Social and Environmental effects in Greece, as various statistics present. We are referred to both. The international data for the atomic bomb survivors are also discussed. In principle the statistical work is very sensitive, due the collected data, and the underlying hidden Mathematics. The analysis needs a particular consideration, based on Statistical techniques, for those exposed to nuclear effect, due to the involved politics.

Keywords: Risk, Statistical Level, Chemicals, Atomic Energy

1. Introduction

On the April 26, 1986 at 01:23 hours the fourth Unit of the Nuclear Reactor at Chernobyl, of the former USSR, has exploded. This unit was supplied with two electrical turbines of 500 MEGAWATT. It was established on 1983, as the third unit, while the first and the second were established in 1977. The technical lake, close to Chernobyl, is about 22 km^2. The environment around Chernobyl, in a radius of about 100 km was heavily polluted. That includes Belaruse, Ukraine, Russia. The pollution was heavily increased due to the rainfall and a lot of people were exposed to the risk due to 1st of May celebration.

The first country tackled by the nuclear cloud was Sweden in April 27, 1986, while in Finland they noticed an unusual increase of radiation. On April 28-30, 1986, Poland, East and West Germany, of that time, Belgium, Holland an U.K noticed and realized the increased radiation in their territory. The nuclear cloud moved up to May 2-3 to Austria, North Italy, the Balkan area and Greece. Due to rainfall of those days the nuclear cloud was essentially realized in northern Greece and particularly in the area of Pieria, Grevena and Trikala, which are roughly 350-450 km northern to Athens.

The Greeks stop eating vegetables and fruits (a rather essential part of the Greek food) and they were certainly panic. As a result 2500 cases of stopping pregnancy were recording these days. Looking back to that days, the panic in Greece, was essentially due to the absence of any strict instructions to the Greek citizens what to do or what to avoid doing.

Various measurements were taken, since that day, to describe the influence to the food products due to the Chernobyl accident etc. Different meetings were also taken place in Greece about this sad event the most appreciated being that of Greek Ca Society on November 27-29 1995, and the meeting of the Greek Research Center "Demokritus", April 22-23, 1996.

The collection of such data it is under various restrictions. In this paper only the Statistical point of view of the problem is under investigation. The terms trueness and precision are used to describe the **accuracy** of a measurement, under the ISO 5725-1 . Trueness refers to the closeness of the mean of the measurement results to the actual (true, but unknown) value. Precision refers to the closeness of agreement within individual results. Therefore, according to the ISO standard, the term "accuracy" refers to both trueness and precision. Moreover it is emphasized that ISO 5725-1 also avoids the use of the Statistical term bias (the expected value of the estimation minus the true value), because it has different connotations outside the fields of science and engineering, as in medicine and law. The following Figure 1 clarifies the situation. Notice that the bias, under the M-estimators, Kitsos and Mueller (1995), can be either bounded by a positive M, or less than infinity – which is actually the classical case of estimation. As we do not know the bounds of the bias, in nuclear data reports, we are under the Classical case of estimation in such cases. We believe that even the consideration of "personal believes" and therefore a Bayesian approach, it would be a Risk procedure.

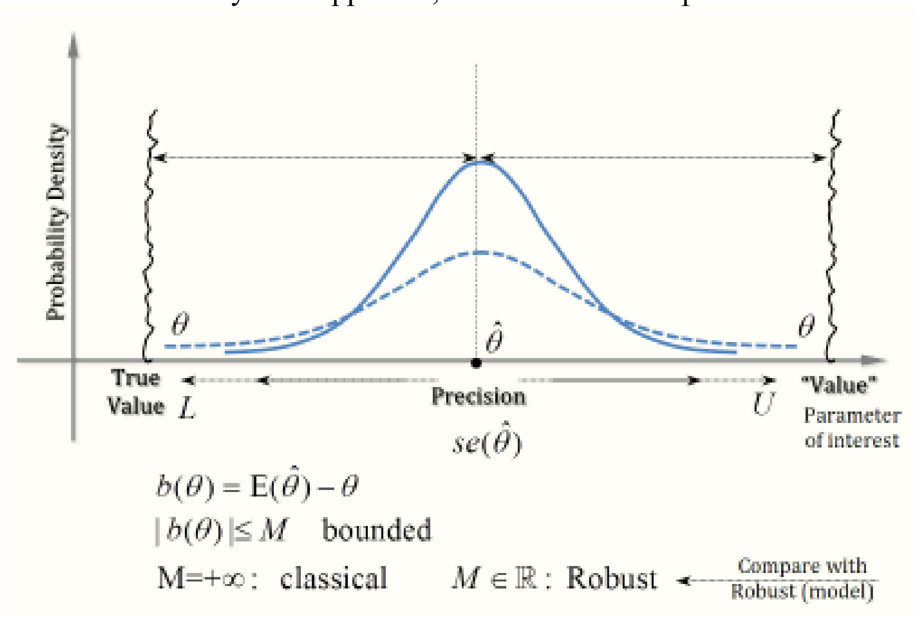

Figure 1: Presenting Bias, Precision and Robust estimation, under the Normal distribution.

The fact that "more probability" is needed at the tails, created a family of distributions with "fat tails". A typical example of such distribution is the γ-order generalized Normal, with an extra (shape) parameter γ, Kitsos and Tavoularis (2009). With value of γ=2, the typical Normal is obtained, while with γ>2, the probability at the tails in a 2σ confidence interval is more that 0.05, see Kitsos and Toulias (2010). In environmental problems, with "extreme situations", as the nuclear events, the γ-order generalized Normal distribution, seems to be more appropriate, as even in a 3σ interval, the tails still devote an essential probability level, to describe the extreme phenomenon, as the Chernobyl nuclear accident- Figure 2 bellow describes the situation in comparison with Figure 1 above, when γ=5.

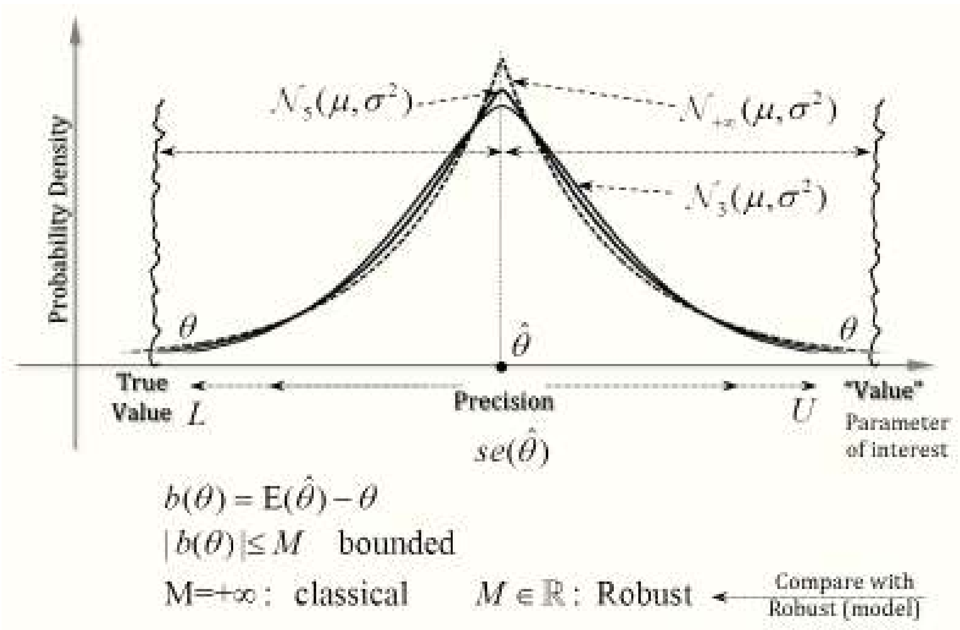

Figure 2: Presenting Bias, Precision and Robust estimation, under the generalized γ-normal distribution (γ=5, to obtain "heavy tails")

The collected data, were the underlying model is not clear, as in Economics, Sociology etc, provides that information which might measure either the existed Uncertainty or the Relative Risk.

In principle, Uncertainty is the lack of certainty: a state of having limited knowledge, where it is impossible to exactly describe the existing state, a future outcome, or more than one possible outcome. It is clear therefore that in nuclear disasters, at least at first stage there is an uncertainty about the event. Thus a Measurement of Uncertainty is needed: A set of possible states or outcomes where probabilities are assigned to each possible state or outcome – this also includes the application of a probability density function to continuous variable. That is the relation with Statistics is certain! Moreover **at a** state of uncertainty there are some possible outcomes with an undesired effect or significant loss. That is the Risk is needed to be estimated. The Relative Risk, or Odds Ratio, is a typical measure of the Risk, see Halkos and Kitsos (2010, 2011, 2012) who adopted this procedure on a number of applications.

That is eventually the Uncertainty, as well as the Risk, for the Sociological and Economical problems is rather more difficult to be evaluated, than in Engineering problems, as the underlying mechanism is not clear and solid. We present briefly some of the data collected and presented for Greece, to measure pollution, due to the Chernobyl nuclear accident in Greece.

2. Statistical Data

There are different data sets and relevant analysis for them, as far as the Chernobyl accident concerns. This paper is concentrated on Greece, but we present as well the main results for other countries, Bazyka et al. (2007). The Data Analysis can be presented either in a compact mathematical point of view, with no chance of numerical evaluations, as in the excellent Mathematical monograph by Tan (1991), or being more realistic and adopting and applied Statistical models in practice, or as compromise between theory and Data Analysis, Edler and Kitsos (2005).

Based on the data of the 2006 National Report of Ukraine (2006), in Table 1 it is presented the following average total (internal and external) cumulative doses may be estimated for 1,446,000 residents in the >37 kBq/m^2 ^{137}Cs original deposition Ukrainian areas over the 1986-2055 period.

Table 1: Cumulative Dose in Ukraine due to Chernobyl accident

Period(s)	**Total Average Cumulative Dose**	**Contributions of the single**
1986	~ 5.4 mSv (30%)	~ 5.4 mSv (30%)
1986-2005	~ 13 mSv (72%)	~ 7.6 mSv (42%)
1986-2055	~ 18 mSv (100%)	~ 5.0 mSv (28%)

The dose distribution is uneven in the various areas. The higher assessed exposures for Ukrainian population (small groups) is: 1986-2005 ~ 100-200 mSv

A high dose variability results also within some very small areas. Following Bazyka et al. (2007), taking into account the IARC estimation criteria of cancer burden, from the Chernobyl accident falloutan assessment of solid cancer incidence risk in the significantly contaminated areas of Belarus, Russia and Ukraine has been carried out for residents. The lifetime risk parameter for solid cancer (7.28 x 10^{-5}/mSv) was adopted.

Different statistical data sets were collected and analyzed in Greece in relation to the Chernobyl accident. Some of them are discussed and presented here, so that a global point of view to be realized for Greece. We would like to emphasize the absence of databases in Greece concerning Ca at the time of accident. The studies ware mainly based on:

Sampling measurements on humans or animals.

Measurements of radiation in the environment.

Experimentation on animals (mainly to test milk).

An overall criticism of the adopted techniques is that although accurate data sets were collected, there are some evidence that there is not an experiment design approach, to be followed, either for the sampling technique adopted (although a simple random sampling scheme was usually used) or for the experimentation. We present the main targets of the measurements below.

2.1 Childhood Leukemia

The full information on the size of the carcinogenic risk of an exposure is given by an exposure-risk relationship (dose-response relationship). Childhood Leukaemia is usually measured in nuclear accidents. More over the radiation of the Sea or more general the Water, Food etc are also measured. In most Risk cases, such as Cancer, it is not reported , the full relationship. Instead a selected one-dimensional feature of the relation is used to characterize the size of the risk, as this is easier not only in evaluation, but in data collection as well.. Examples are the Virtual Safe Dose (VSD), the Benchmark Dose (BMD), the effective dose that causes xx percent of responses (EDxx), the Unit Risk (UR), or the NOAEL. These quantities represent different properties of the dose-response relationship. The data collected for the accident under investigation, has been extensively criticized. We shall restrict our interest for the case of Greece.

Childhood leukemia is a crucial subject as the average time of its appearance is eight years when a child is exposed to radiation, while is known that it is related to radiation. It was counted the soil radiation (in Bq/kg Ra-226) and the radiation Cs-117 in the 52 districts of Greece, Petridou et. al. (1994). For the period of time 1.1.80 – 30.6.86 there was a frequency of 3.67 cases of children leukemia per 100.000 children, while for the period 1.7.86 - 30.6.88 there was a frequency of 3.99 and then from 1.1.88 - 30.6.91 came back to usual level, a 3.39 frequency per 100.000 was recorded. There is a criticism for this study, but even so, there are not enough evidence to announce a statistical significant difference before and after the accident, while it might be an effect due to low dose absorption of radiation. This has not been studied. Only a descriptive statistics analysis was preceded.

2.2 The radiation of the Sea

From the experimental dose-response relationship, see Kitsos (2012) it is possible to obtain the highest dose level (that is an explanation of why some researchers adopt the Extreme Value Theory) for which no significant effect is detected. The term describing the situation is in Toxicology No-Observed-Effect-Level, NOEL. The situation is complicated as different NOELs may exist, when different target and tissues or different species are considered. As a rule of thump the mini-max dose effect is adoped, ie choose the minimum NOEL to reduce uncertainty. But unfortunately the extrapolation from the experimental NOEL to humans needs further investigation, Kitsos (2012), among others.
Therefore the radiation of the sea, might be considered as a source of information for the life within the sea. The data we considered for Greece is describing briefly. The Cs-137 levels between 1984-1985, for the Aegean Sea was about 2-3 $B_2\ m^{-3}$. As it was reported by Kritidis et. al. (1990) and Florou et. al. (1990) the Cs-137 was increased to 3-4 Bqm^{-3} while the Cs-137 was also performed to test the influence of Cs-137, Cs-134 to the fish ecosystems at the Greek lakes.

2.3 The radiation of the Water

It is a very complicated case of study the fate and transport of chemicals in groundwater. In principle fate and transport of a contaminant from a spource to a potential exposure site can be divided in the following main steps:

Release of contaminant into the ground

Movement of contaminant through an unsaturated zone OR

Movement of contaminant through a saturated zone.

Release of the material into the groundwater is certainly required – not an easy procedure. The involved uncertainty in characterizing the release of chemicals into the geo-hydrologic system passes through the following levels:

Decide/describe chemicals are present

What is the receptor medium?

Define or guess when the realize will begin.

What is the expected rate of release?

For how long will take place in level 4 release.

Therefore to investigate the influence of the accident to the "neighborhood area" is not that easy, as gar as the chemical concern. Moreover is difficult to define the "radius" of the "neighborhood area". That is why in this paper only Greek collected data is reported. On the report of "Demokritus" Research Center (1989) different values for rainwater, surface water concerning the lakes Marathon and Iliki and the river Mornos, as the three of them are the source of the drinking water in Athens. Values for the drinking water of any kind in Greece are reported as follows in Table 2.

Table 2: Mean Values of I-131 and (Cs-137 + Cs-134) for water samples after Chernobyl accident in Greece

Period	Rainwater	Surface	Drinking
1. May 5-11,1986	92 (A)	25 (ND*)	11.0 (1)
2. May 12-18,1986	3.6 (1.3)	2.6 (2)	1.6 (1.8)
3. May 19-25,1986	5.5 (1.5)	ND (ND)	2.9 (0.5)
4. May 26-June 1,1986	0.8 (0.8)	ND (ND)	1.5 (ND)

* ND = Not Defined

Therefore all the values reported are below 1.1 BqI^{-1} after May 30,1986. An extente research on drinking water disinfectants and contaminants, can be find in IARC (2004), were an extended list of references is also presented.

2.4 The radiation of the Woods

The average value of Cs-137 on the surface oil (AVSS) in a wood is due to its leaves from the trees (for about 83%) and to its branches from the trees (for about 17%). In Greece is AVSS = 0.18 $MBqha^{-1}y^{-1}$ and the contribution due to the rainfall of that days was not significant. It is crucial to notice here that due to large uncertainties, and woods might offer such a possibility, the risk of making scientific mistakes is large.

The two most important cases are "false positives" and "false negatives".

A false positive is a misclassification in which a substance is judged to be carcinogenic, when in fact it is not. A false negative is a misclassification in which a substance is judged not to be carcinogenic, when in fact it is. That is why the Statistical Data Analysis is very important in such cases.

2.5 The radiation to the Food

Different samples were collected in Greece during May 3 – June 25,1986. A simple integrated factor was introduced, as the Factor of Emergency, FE. It is based on the NRPB Derived Emergency Reference Levels and, see "Demokritus' report (1986). It reflects the level of emergency a given mixture of concentrations for each age group, ie.

$$FE_j = \sum_i \frac{C_i}{L_{ij}}$$

with C_i : the concentration of nuclide i

L_{ij} : the NRPD DER Level for nuclide i and age group j

Various products were tested due to this idea. In principle, as it is reported, by the middle of June 1996 the FE values were at the expected range. From Papastefanou et. al. (1996) who extensively discussed the pollution from Chernobyl accident, we present the average concentrations of Cs-137 in food stuff in Greece.

Table 3: Mean concentrations and standard deviation (SD) of Cs-137 (*) in foodstuff (Bq kg^{-1}) in Greece, May 1986-May 1987.

Mean concentration ± SD (Bq kg^{-1})	Food Stuff
130 ± 8	cheese, milk, vegetables
150 ± 9	bread, meat
350 ± 2	cereals
20 ± 1.2	potatoes
120 ± 7	fruits

(*)Yearly intake C_5-137 (Bqg^{-1}) = 82072.5

2.6 Various other measurements

Various other measurements were taken in Greece to test the effect Chernobyl accident in pollution. To test the effect of Cs-137 in humans. The maximum values of surface radiation were found at the area of Imathia and Karditsa. To test the effect Sr-90 to human teeth and bones. The following Table 3 presents the concentration of Sr-90 in bones, Stamoulis et. al. (1996).

Table 4: Concentration of Sr-90 in human bones

Age	m Bq Sr-90/g Ca
20-30	13± 2
30-40	33±19
40-50	33±21
50-60	46±13
60-70	51±37
70-80	37±10

These values are within the usual levels. But we believe that the sample size is very small.

2.7 Comments

We believe that, in principle, there is a weak statistical analysis at the collected data in Greece. Either the small sample size, or the statistical method adopted does not provide too much evidence that the results are statistically significant. But as they stand, most of the analysis provided for the influence of various chemicals does not provide a statistical significant influence. But the chemicals are measured one by one for sort time to restricted number of cases. Most of the authors realized the underlying statistical problem. There are not studies working the effect of chemicals as covariates, Kitsos(1998).

3. Dose estimates for the Greek population

In section 2 we summarize in a compact form, the radioactive materials contaminating the Greek environment and the Greek foodstuffs. There is a certainly a geographical factor : the influence was substantial in the North Greece. The routes of exposure offer a different degree of ionizing radiation. The effect was different from adults and children.

The assumptions for a interval evaluating exposure and to water ingestion were, "Demokritus" (1986). A daily inhalation rate of 23 m^3 for adults and 15 m^3 for the ten years old children. Then from May 2-31,1986 the effective dose equivalents were estimated to 5 and 7 m rem. A daily water intake of 1.65 lt and 0.95 lt for the children age 10. Then the radioactive burden due to water ingestion was at most 249 Bq and 143 Bq respectively. The following Table 5 summarizes the results.

The Cancer data concerning the Greek society have been published by Stavrakakis et. al. (1991) at an official publication. Kitsos (1991) working with the Medical School Of the Technological Education Institute, performed an one year study collected data on Ca from the Greek hospital records. Meanwhile a social and epidemiological study was carried out, with a sample of 3000 Athenian households to study the social-economic factors on the Ca.

There is indeed a statistical significant difference among various areas in Athens. There is also a statistical difference between Athens and some areas in the North, but still this is rather hard to decide if this is due to the Chernobyl accident. The time the Greek patients remain at hospital concerning a therapy on Ca has been studied by Kitsos et.al.(1991).

Table 5: Global dose estimates in mrem for the first year of the accident in Greece

Route of exposure	Adults	Children age 10
Inhalation	4.6	6.8
External exposure	24.6	24.6
Drinking water	1.0	1.0
Food ingestion		
I-131	5.0	18.4
Cs-137/134	75.4	97.2
Total	111.0	148.0

It is needed a particular statistical analysis if these global dose estimates, in children and adults have a true statistical effect or they acted as covariates, Kitsos (1998).

4. Discussion

The Greek population was exposure the fallout from the Chernobyl's nuclear accident through inhalation of airborne material from material deposited on the ground and therefore ingestion of contaminated foodstuffs.

Most of the studies carried out in Greece on humans were based either on epidemiological studies on different measurements. A typical example is the measurements the Cs-137 in various tissues of persons who died in accidents, in Northern Greece, Thessaloniki, Metropolitan area, 8 to 10 months after the Chernobyl accident, Papastefanou et. al. (1999). They estimated a total value about 1.06 mSV (106 mrem), which is roughly equal to the typical annual absorbed dose from natural resources. Moreover the presented values adjust (by half!) previous estimation of theirs.

That is there is not often a solid framework and a method to provide accurate estimates. The influence of the pollution to high-risk groups has certainly worked out as a covariate, Kitsos (1998). To my knowledge there are such studies, which is to examine if the effect even of low-level radiation has acting as a low dose. A theoretical approach to the low dose extrapolation problem has been discussed by Kitsos (1999). It has not been concluded a clear statistical significant effect due to the accident, in most of the Greek studies, concerning Greece, appeared in Greece. But we notice that the studies were base on descriptive Statistics and there was not a study on the influence of thunderlying existing mechanism, for developing Ca, Moolgavkar and Luebeck (1992).

We are all referring to the negative points of the Chernobyl accident and we investigate the pollution influence, offering our small contribution to science. But we should offer our tribune to the workers of Chernobyl who despite the circumstances proved themselves brave and faithful to their duty.

ACKNOWLWDGMENTS

The generous support of CCMS/NATO on the Cancer study (1990-2008) is very much appreciated. The useful comments of Professor George Halkos, helped the improvement of the paper.

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Αξιολόγηση μελέτης περιβαλλοντικών επιπτώσεων με χρήση αλγορίθμου ποιότητας

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Περίληψη

Ο στόχος της παρούσας εργασίας είναι να προτείνει ένα σύστημα αξιολόγησης για Μελέτες Περιβαλλοντικών Επιπτώσεων (ΜΠΕ) με προδιαγραφή και δημιουργία ενός αλγόριθμου ποιότητας. Στην αρχή αξιολογούνται οι λόγοι που καθιστούν αναγκαίες τέτοιου είδους μελέτες και παρατηρείται ότι παρά το υπάρχον νομικό πλαίσιο στην Ελλάδα, αρκετές ΜΠΕ κρίνονται ανεπαρκείς. Στη συνέχεια προσδιορίζονται κατηγορίες ποιοτικών και ποσοτικών κριτηρίων με βάση τα οποία συντάσσεται ένας γενικός τύπος βαθμονόμησης με χρήση συντελεστών βαρύτητας για την εκάστοτε κατηγορία. Η επιλογή των κριτηρίων αλλά και η βαθμονόμησή τους γίνεται με βάση τη σπουδαιότητα που έχουν και τεκμηριώνονται με σημερινές κοινά αποδεκτές βιβλιογραφικές πηγές. Για να διαπιστωθεί η ορθή εφαρμογή του συστήματος βαθμονόμησης, γίνεται μια εμπεριστατωμένη αξιολόγηση μιας Προμελέτης Περιβαλλοντικών Επιπτώσεων που αφορά ένα έργο αντιδιαβρωτικής προστασίας στην περιοχή της Μεθώνης. Απ' τα αποτελέσματα που προκύπτουν, διαπιστώνονται οι ελλείψεις της μελέτης και η ΠΠΕ κρίνεται τελικά με εφαρμογή του αλγόριθμου. Συμπεραίνεται ότι ένα λεπτομερές σύστημα βαθμονόμησης αποκαλύπτει όλες τις ελλείψεις και τα λάθη μιας Μελέτης Εκτίμησης Περιβαλλοντικών Επιπτώσεων. Τέλος εξετάζεται πώς η προτεινόμενη μέθοδος αξιολόγησης μπορεί μελλοντικά να βελτιωθεί.

Λέξεις Κλειδιά- Q51: (Μελέτη Περιβαλλοντικών Επιπτώσεων) ΜΠΕ;(Περιβαλλοντικές Μελέτες) ΠΜ; αλγόριθμος; Ποιοτικά Κριτήρια Αξιολόγησης- Βαθμονόμησης.

Abstract

The aim is to propose a system of evaluation for Environmental Impact Assessments (EIA) in order to configure and create a quality algorithm. In the beginning we evaluate the reasons which necessitate such studies and its structure. Then we specify categories with qualitative and quantitative criteria, on which are based on a generic calibration

method (algorithm), using weighting coefficients for each category. The selection criteria and the calibration are based on the importance they have and are supported by current commonly accepted bibliographic sources. Moreover, a proper application of the system calibration has been tested by a thorough evaluation of a Preliminary Design of Environmental Impact Assessments (PDIA), concerning an anti-corrosion protection project on the area of Methoni. From the results obtained, it revealed some shortcomings of the study and the PDIA is finally being implemented by the algorithm. It can be concluded, that a detailed system calibration reveals all the errors and omissions of an EIA. Finally, we consider how the proposed method of evaluation in future can be improved.
Keywords-Q51: **(**Environmental Impact Assessments**)** EIA; **(**Environmental Studies**)** ES; algorithm; qualitative criteria of evaluation-calibration.

1. Εισαγωγή

Η εκπόνηση Μελέτης Περιβαλλοντικών Επιπτώσεων (ΜΠΕ) και αντίστοιχα Προμελέτης Περιβαλλοντικών Επιπτώσεων (ΠΠΕ) για ένα τεχνικό έργο, έχει διαδοθεί πάρα πολύ τα τελευταία 30 χρόνια σε αρκετές χώρες του κόσμου και έχει γίνει ένα αναπόσπαστο κομμάτι των οικοδομικών κανονισμών τους που αφορούν το περιβάλλον. Συγκεκριμένα, οι ΠΠΕ, ΜΠΕ εκπονούνται σε περισσότερες από 100 χώρες του κόσμου **[1].** Στους οικοδομικούς κανονισμούς κάθε χώρας αναφέρονται συνήθως οι προδιαγραφές που πρέπει να τηρούνται για μια ΜΠΕ προκειμένου αυτή να θεωρείται επαρκής. Ωστόσο, είναι σύνηθες να χρησιμοποιούνται για την αξιολόγηση μιας ΜΠΕ κάποιες εμπειρικές πρακτικές, που βασίζονται κυρίως σε ποιοτικά κριτήρια, όπως είναι η χρήση αξιόπιστων μοντέλων πρόβλεψης **[2]** και η ύπαρξη εντός της μελέτης αρκετών εναλλακτικών προτάσεων **[3].**

Η χρήση ποιοτικών συντελεστών για την αξιολόγηση μιας ΠΠΕ ή ΜΠΕ, πέραν της υπάρχουσας αντίστοιχης κυβερνητικής νομοθεσίας, γίνεται επιτακτική ανάγκη στην περίπτωση της Ελλάδας. Η Ελλάδα ήταν ένα από τα τελευταία κράτη – μέλη της Ευρωπαϊκής Ένωσης, που υιοθέτησαν στους οικοδομικούς κανονισμούς τους την υποχρεωτική εκπόνηση ΠΠΕ και ΜΠΕ για κάθε τεχνικό έργου μεσαίου και μεγάλου βεληνεκούς. Το νομικό πλαίσιο στην Ελλάδα συντάχθηκε το 1986 **[4],** και το κείμενο κατηγοριοποιεί τα τεχνικά έργα σε σχέση με τη σπουδαιότητά τους και ορίζει τον αντίστοιχο τύπο της μελέτης αλλά και τα κριτήρια που πρέπει να τηρεί αυτή. Το 2002, υπήρξε μια τροποποίηση των κανονισμών αυτών με βάση τα αντίστοιχα ευρωπαϊκά πρότυπα. Δυστυχώς, μέχρι να υπάρξει αυτή η τροποποίηση στους κανονισμούς, όπου αρκετές διατάξεις έγιναν σαφέστερες και οι προδιαγραφές αυστηρότερες, είχαν προηγηθεί πάρα πολλά τεχνικά έργα μεγάλης εμβέλειας στα οποία είχε συνταχθεί ΜΠΕ με βάση τους κανονισμούς του 1986.

Ο σκοπός της παρούσας εργασίας είναι να μορφώσει ένα σύστημα αξιολόγησης ΠΠΕ χρησιμοποιώντας κατά βάση ποιοτικούς συντελεστές βαθμονόμησης. Η επιλογή των συντελεστών βαρύτητας έγινε με βάση τα όσα αναφέρονται στη διεθνή βιβλιογραφία και τη σπουδαιότητα κάθε κατηγορίας **[5], [6], [7],** αλλά κυρίως ακολουθώντας με κάποιες τροποποιήσεις το μοντέλο των ποιοτικών συντελεστών που χρησιμοποιήθηκε στην εργασία του Ανδρουλιδάκη και Καρακάσση το 2006 **[8]**. Η μόρφωση του συστήματος βαθμονόμησης το οποίο προτείνεται, ελέγχεται μέσω μιας πρακτικής εφαρμογής, δηλαδή την αναλυτική αξιολόγηση και βαθμολόγηση μιας υπάρχουσας ΠΠΕ που συντάχθηκε στο διάστημα 1986-2003, όταν και οι ελληνικοί κανονισμοί δεν ακολουθούσαν τα ευρωπαϊκά πρότυπα.

2. Μεθολογία

Το σύστημα βαθμονόμησης κάθε ΠΠΕ ή ΜΠΕ βασίζεται σε 8 κατηγορίες κριτηρίων αξιολόγησης. Η τελική βαθμολογία θα προκύπτει ως ένα ποσοστό επί τις εκατό. Ανάλογα με την τελική σταθμισμένη βαθμολογία η ΠΠΕ θα κατατάσσεται σε μια από τις ακόλουθες 4 κατηγορίες:

1) Ελλιπής (0-50%)
2) Φτωχή (51-65%)
3) Μέτρια (65-80%)
4) Επαρκής (81%-100%)

Η παραπάνω κατάταξη βασίστηκε στην κωδικοποίηση που πρότεινε στην εργασία του ο Glasson et al, 1999 **[3].**

Υπάρχουν 8 ειδικές κατηγορίες στις οποίες αντιστοιχούν διάφοροι παράγοντες στην καθεμιά. Σε καθεμιά ειδική κατηγορία δόθηκε ένας συντελεστής βαρύτητας, με βάση και διάφορες βιβλιογραφικές αναφορές, (**[8], [9], [10]**) και κυρίως τις εργασίες των Ανδρουλιδάκη και Καρακάσση (2006), Hodson et al (2001), Glasson et al (1999). Συγκεκριμένα, θεωρήθηκε ότι οι κατηγορίες κριτηρίων με αυξημένη βαρύτητα είναι:

Α) ο προσδιορισμός των επιρροών και πρόβλεψη (20%) ,
Β) Εξουδετέρωση Αρνητικών Συνεπειών (15%),
Γ) Εναλλακτικές επιλογές (15%).

Για τις υπόλοιπες κατηγορίες κριτηρίων, θεωρήθηκαν μέσης σημασίας οι ακόλουθες:

Α) Περιγραφή περιβάλλοντος (14%),
Β) Περιγραφή του έργου (14%).

Τέλος, ελάσσονος σημασίας θεωρήθηκαν οι ακόλουθες κατηγορίες κριτηρίων:

Α) Έρευνα ρίσκου (8%),
Β) Βιβλιογραφία (7%),
Γ) Αναφορά στη δημόσια συμμετοχή (7%).

Αναλυτικά το σύστημα βαθμονόμησης φαίνεται στον Πίνακα 1.

Λαμβάνοντας υπόψη τους παραπάνω συντελεστές προκύπτει ο ακόλουθος τελικός τύπος βαθμολόγησης:

$$\begin{aligned} Grade = {} & 2,3\% * (A_1 + A_2 + A_3 + A_4 + A_5 + A_6) + \\ & 3,5\% * (B_1 + B_2 + B_3 + B_4) + \\ & 3,3\% * (\Gamma_1 + \Gamma_2 + \Gamma_3 + \Gamma_4 + \Gamma_5 + \Gamma_6) + \\ & 0,5\% * (\Delta_1 + \Delta_2 + \Delta_3) + 0,5\% * (\mathrm{E}_1 + \mathrm{E}_2 + \mathrm{E}_3) \\ & 2,67\% * (\Sigma\mathrm{T}_1 + \Sigma\mathrm{T}_2 + \Sigma\mathrm{T}_3) \\ & 3,5\% * (\mathrm{Z}_1 + \mathrm{Z}_2) + 3,5\% * (\mathrm{H}_1 + \mathrm{H}_2) \end{aligned} \quad \textbf{(1)}$$

Ο κατάλογος των κριτηρίων χωρίζεται σε οκτώ τμήματα. Η πρώτη ενότητα πραγματεύεται την κατάσταση του περιβάλλοντος όπου το έργο πρόκειται να αναπτυχθεί. Ιδιαίτερη αναφορά γίνεται στο φυσικό περιβάλλον όπου και εξετάζονται στοιχεία σχετικά με τα κλιματικά, βιοκλιματικά, μορφολογικά, γεωλογικά, τεκτονικά χαρακτηριστικά της περιοχής. Ένα βασικό στοιχείο για την ολοκληρωμένη αξιολόγηση είναι η συμπερίληψη ενός γεωλογικού χάρτη της περιοχής του έργου σε κατάλληλη κλίμακα **[9]**. Τα χαρακτηριστικά της πανίδας και της χλωρίδας της περιοχής του έργου εξετάζονται επίσης και δίνεται ιδιαίτερη προσοχή σε περιπτώσεις ύπαρξης στην περιοχή απειλούμενων ειδών. Επιπλέον, κατά την περιγραφή των κοινωνικοοικονομικών χαρακτηριστικών του περιβάλλοντος, γίνεται προσπάθεια να συγκριθούν τα οικονομικά οφέλη που προκύπτουν από το έργο με τις αρνητικές μπορεί να έχει στο κοινωνικό και φυσικό περιβάλλον στη φάση της κατασκευής και λειτουργίας του. **[3]** Στην πρώτη κατηγορία κριτηρίων γίνεται μια αναλυτική περιγραφή της τρέχουσας κατάστασης της ρύπανσης καθώς και μια αναφορά σε άλλα παρόμοια έργα στην περιοχή του έργου.

Το δεύτερο τμήμα περιλαμβάνει τη λεπτομερή περιγραφή του κύκλου ζωής του έργου, η οποία αποτελείται από τα στάδια του σχεδιασμού του έργου, την κατασκευή, τη λειτουργία, τον παροπλισμό και την αποκατάσταση. Επιπλέον, δίνονται επιχειρήματα για την αναγκαιότητα του έργου μέσα στο κοινωνικό περιβάλλον όπου πρόκειται να ενταχθεί και προτείνονται απαντήσεις για τις αντιρρήσεις που μπορεί να προκύψουν.

Η τρίτη ενότητα αφορά το προσδιορισμό και την πρόβλεψη των επιπτώσεων του έργου. Οι επιπτώσεις κατηγοριοποιούνται ως θετικές - αρνητικές , άμεσες ή δευτερεύουσες και ανάλογα με τη σημασία τους. Η εκτίμηση των επιπτώσεων σύμφωνα με τις προαναφερθείσες κατηγορίες απαιτεί όχι μόνο ποσοτικό, αλλά κυρίως ποιοτικό προσδιορισμό. Αυτό το στάδιο της αξιολόγησης είναι ο κύριος άξονας της αξιολόγησης μιας ΠΠΕ. Ο ποσοτικός και ποιοτικός προσδιορισμός των τυχόν περιβαλλοντικών αλλαγών που συμβαίνουν λόγω της υλοποίησης του συγκεκριμένου έργου είναι ο κύριος ρόλος της αξιολόγησης και θα πρέπει να πραγματοποιηθεί πιθανόν με τη χρήση των κατάλληλων μοντέλων. **[3]**

Το στάδιο αντιμετώπισης των αρνητικών επιπτώσεων μελετάται στην τέταρτη ενότητα, παράλληλα με την καταλληλότητα των προτεινόμενων μέτρων και αποτελεί ένα από τα θεμελιώδη τμήματα της διαδικασίας. Στο κριτήριο αυτό εξετάζεται κατά πόσον ο ανάδοχος της μελέτης έχει τα κατάλληλα επιστημονικά προσόντα και τη θέληση για να εξαλείψει όλες τις δυσμενείς επιπτώσεις που προκαλούνται από ένα έργο ή μια δραστηριότητα στο περιβάλλον. Η παρακολούθηση διαδραματίζει σημαντικό ρόλο στην επίτευξη αυτού του στόχου. Σκοπός της επιτήρησης είναι να συγκεντρώσει όλες τις σχετικές πληροφορίες για τα χαρακτηριστικά και τη χωρική και χρονική εξέλιξη των αλλαγών και, κυρίως, για την πρόβλεψη της εμφάνισης και του μεγέθους των επιπτώσεων . Αυτό το στάδιο σε πολλές ΠΠΕ, ειδικότερα στην Ελλάδα, συχνά παραλείπεται.

Οι ΜΠΕ και ΠΠΕ θα πρέπει να περιλαμβάνουν την παρουσίαση των εναλλακτικών σεναρίων που εξετάστηκαν από τη μελέτη αναδόχου, καθώς και την αξιολόγησή τους και την αιτιολόγηση της τελικής επιλογής. Η επιλογή της «μη ενέργειας» μπορεί να είναι μια εναλλακτική λύση και ως εκ τούτου απαιτείται συζήτηση για την αναγκαιότητα του προτεινόμενου του έργου ή της δραστηριότητας. Η εκτίμηση κινδύνου (risk assessment) και η αναφορά στις αναμενόμενες πιθανότητες αστοχίας παρουσιάζονται στην έκτη ενότητα κριτηρίων. Ο ανάδοχος της μελέτης, λαμβάνοντας υπόψη όλους τους πιθανούς κινδύνους, θα πρέπει να προβλέψει και να ελαχιστοποιήσει την πιθανότητα της αποτυχίας με την υιοθέτηση μιας σειράς πρόσθετων μέτρων. Όλοι οι συντελεστές του έργου πρέπει να λαμβάνονται υπόψιν σε αυτό το στάδιο. Τα αποτελέσματα που λαμβάνονται σχετικά με την αναγκαιότητα του έργου εξάγονται με βάση τη σχέση κόστους –οφέλους, καθώς την ικανοποίηση των κοινωνικών αναγκών. Επιπλέον, τυχόν προβλήματα ή αβεβαιότητες που έχουν προκύψει κατά την εκπόνηση της μελέτης θα πρέπει να αναφερθούν σε αυτό το τμήμα της ΠΠΕ, μαζί με τις παραδοχές που έγιναν προκειμένου να ξεπεραστούν.

Πίνακας 1: Κατηγορίες κριτηρίων βαθμονόμησης ΠΠΕ

ΕΞΕΤΑΖΟΜΕΝΑ ΚΡΙΤΗΡΙΑ
Α) Περιγραφή Περιβάλλοντος (14%)
Α1. Περιγραφή φυσικού περιβάλλοντος (1/6*14%)
Α2. Περιγραφή κοινωνικού περιβάλλοντος (1/6*14%)
Α3. Περιγραφή των τρεχόντων επιπέδων μόλυνσης (1/6*14%)
Α4. Αναφορά σε υπάρχοντα παρόμοια έργα στην περιοχή (1/6*14%)
Α5. Δυναμική του περιβάλλοντος σε περίπτωση απουσίας του έργου (1/6*14%)
Α6. Χλωρίδα/Πανίδα (αναφορά σε παρόμοια συστήματα) (1/6*14%)
Β) Περιγραφή του έργου (14%)
Β1. Περιγραφή του προτεινόμενου έργου και της φάσης κατασκευής (1/4*14%)
Β2. Περιγραφή της φάσης λειτουργίας του έργου (1/4*14%)
Β3. Ανάλυση του συνολικού κύκλου ζωής του έργου (1/4*14%)
Β4. Αιτιολόγηση της αναγκαιότητας του έργου (1/4*14%)
Γ) Προσδιορισμός των επιρροών και πρόβλεψη (20%)
Γ1. Προσδιορισμός επιρροών (κατάλογοι, πίνακες, GIS, κλπ) (1/6*20%)
Γ2. Εκτίμηση θετικών και αρνητικών επιρροών (1/6*20%)
Γ3. Εκτίμηση έμμεσων και δευτερευόντων επιρροών (1/6*20%)
Γ4. Εκτίμηση βασικών και λιγότερο σημαντικών επιρροών (1/6*20%)
Γ5.Χρήση των κατάλληλων μοντέλων πρόβλεψης (1/6*20%)
Γ6. Σαφήνεια και ακρίβεια της πρόβλεψης (1/6*20%)
Δ) Εξουδετέρωση αρνητικών συνεπειών (15%)
Δ1. Προτάσεις μέτρων για εξουδετέρωση αρνητικών συνεπειών (1/3*15%)
Δ2. Σαφήνεια των μέτρων (1/3*15%)
Δ3. Μέθοδοι ελέγχου και προτάσεις (1/3*15%)
Ε) Εναλλακτικές επιλογές (15%)
Ε1. Αναφορά σε εναλλακτικές (1/3*15%)
Ε2. Αναφορά σε διαδικασίες για την επιλογή μεταξύ των εναλλακτικών (1/3*15%)
Ε3. Σύγκριση με την επιλογή «μη ενέργειας» (1/3*15%)
ΣΤ) Έρευνα ρίσκου (8%)
ΣΤ1. Έρευνα ρίσκου και αναφορά σε πιθανότητες αποτυχίας (1/3*8%)
ΣΤ2. Ανάλυση κόστους-οφέλους και τεχνικές οικονομικής αποτίμησης (1/3*8%)
ΣΤ3. Αναγνώριση και εκτίμηση των πηγών αβεβαιότητας (1/3*8%)
Ζ. Βιβλιογραφία (7%)
Ζ1. Αναφορά σε νομοθετικές βιβλιογραφικές πηγές (1/2*7%)
Ζ2. Λοιπή βιβλιογραφία (1/2*7/%)
Η. Αναφορά στην δημόσια συμμετοχή (7/%)
Η1. Συνεισφορά κοινού στην ανάπτυξη μιας μελέτης περιβαλλοντικών επιπτώσεων (½*7/%)
Η2. Σαφήνεια περιεχομένου μελέτης στο μη ειδικό (½*7/%)

Επιπλέον, πρέπει να διευκρινιστεί κατά πόσον τα δεδομένα που χρησιμοποιούνται κατά τη διάρκεια της μελέτης προέκυψαν από επί τόπου μετρήσεις του ανάδοχου της μελέτης ή βρέθηκαν μέσω άλλων πηγών Όταν τα δεδομένα από άλλες πηγές χρησιμοποιούνται, κάθε πηγή πρέπει να προσδιορίζεται σαφώς όπως απαιτείται από το Νόμο περί προστασίας των δικαιωμάτων πνευματικής ιδιοκτησίας

Η όγδοη ενότητα περιλαμβάνει όλες τις αναφορές για τη συμμετοχή του κοινού στο σχεδιασμό του έργου και ως εκ τούτου, τη συμβολή του στην εκτίμηση των επιπτώσεων στο περιβάλλον. Η συμμετοχή του κοινού απαιτείται κατά τη διάρκεια της εκπόνησης των εν λόγω μελετών, αφού οι κάτοικοι της περιοχής του έργου είναι εκείνοι οι οποίοι συνεχώς επηρεάζονται τόσο κατά την κατασκευή όσο και κατά τη λειτουργία του έργου. Ως εκ τούτου, είναι σημαντικό η ΜΠΕ και η ΠΠΕ να είναι γραμμένες με τέτοιο τρόπο ώστε ένας μη ειδικός να μπορεί να διαβάσει και να κατανοήσει τη σημασία των στοιχείων που περιλαμβάνεται σε αυτές.

3. Εφαρμογή

Για να διαπιστωθεί πρακτικά το πόσο εύχρηστο είναι το παραπάνω σύστημα βαθμονόμησης μια ΠΠΕ, έγινε εφαρμογή του σε μια υπάρχουσα ΠΠΕ που αφορά ένα έργο αντιδιαβρωτικής προστασίας σε μια παραλιακή περιοχή στη Μεθώνη. Η συγκεκριμένη μελέτη αποσκοπεί στην ορθολογική διαχείριση της παράκτιας ζώνης της Μεθώνης και την ταυτόχρονη προστασία της από την κυματική δράση ώστε να επιτευχθεί η περιβαλλοντική ανάπτυξη της περιοχής **[10]**. Για το σκοπό αυτό συντάχθηκε η συγκεκριμένη μελέτη η οποία παρουσιάζει τις περιβαλλοντικές επιπτώσεις στην περιοχή εξαιτίας των εργασιών που αφορούν τα αντιδιαβρωτικά έργα. Συντάσσεται στα πλαίσια υλοποίησης των ενεργειών του Δ΄ σταδίου της προγραμματικής σύμβασης, η οποία υπογράφηκε μεταξύ της Περιφέρειας Πελοποννήσου, της Νομαρχιακής Αυτοδιοίκησης Μεσσηνίας του Δήμου Μεθώνης, του Δήμου Αιπείας και της Αναπτυξιακής Μεσσηνίας.

Το έργο κατατάσσεται στην πρώτη υποκατηγορία της πρώτης κατηγορίας στην ομάδα $3^{η}$: «Λιμενικά Έργα» παράγραφος 10 **[4]**: «Έργα προστασίας και διαμόρφωσης ακτών», του Παραρτήματος 1 της ΚΥΑ 15393/2332/5-8-2002 (ΦΕΚ 1022/Β/5-8-2002), καθώς το συνολικό μήκος παρέμβασης είναι περίπου 2km. Η ευρύτερη περιοχή του έργου έχει ενταχθεί στον κατάλογο των προστατευμένων περιοχών του δικτύου Natura 2000, με τον κωδικό GR2550007 (Θαλάσσια Περιοχή Στενού Μεθώνης) και με κωδικό GR2550003 (Νήσοι Σαπιέντζα και Σχίζα, Ακρωτήριο Ακρίτας). Ειδικότερα η ευρύτερη θαλάσσια περιοχή βρίσκεται εντός των ορίων της «θαλάσσιας περιοχής Στενού Μεθώνης» και η παράκτια (χερσαία) περιοχή βρίσκεται εντός των ορίων της περιοχής «Νήσοι Σαπιέντζα και Σχίζα, Ακρωτήριο Ακρίτας». Επιπλέον, ο οικισμός της Μεθώνης και η περιοχή του Κάστρου, έχουν χαρακτηριστεί ως τοπία ιδιαίτερου φυσικού κάλλους λόγω των διατηρητέων - παραδοσιακών κτισμάτων που συναντώνται στη Μεθώνη και της αρχαιολογικής περιοχής του κάστρου (Κωδικός ΑΤ1011083). Το περιεχόμενο της μελέτης είναι σύμφωνο με την ΚΥΑ69269/5387/20-10-90 (ΦΕΚ 678/Β/90): «Κατάταξη έργων και δραστηριοτήτων σε κατηγορίες, περιεχόμενο Μελέτης Περιβαλλοντικών Επιπτώσεων (ΜΠΕ) και λοιπές συναφείς διατάξεις σύμφωνα με το Ν.1650/1986», όπως αυτή ισχύει σήμερα, με το Ν. 3010/2002 (ΦΕΚ 91/Α/2002), την ΚΥΑ 15393/2332/2002 (ΦΕΚ 1022/Β/2002) και την ΚΥΑ Η.Π. 11011/703/Φ104/2003 (ΦΕΚ 332/Β/2003). Έγινε ανάλυση της επάρκειας της συγκεκριμένης μελέτης ως προς τα ποιοτικά κριτήρια που προαναφέρθηκαν και σε κάθε κριτήριο δόθηκε βαθμός. Στο τέλος προέκυψε αθροιστικά η τελική βαθμολογία της ΠΠΕ. Τα αποτελέσματα και οι βαθμοί για κάθε κριτήριο φαίνονται στον Πίνακα 2.

ΠΙΝΑΚΑΣ 2: Αποτελέσματα αξιολόγησης ΠΠΕ ανά ποιοτικό κριτήριο.

ΚΡΙΤΗΡΙΟ		**Συντελεστής Βαρύτητας**	**Επάρκεια**	**Συνεισφορά**
Α	Α1	2,30%	100,00%	*2,30%*
	Α2	2,30%	85,00%	*1,96%*
	Α3	2,30%	85,00%	*1,96%*
	Α4	2,30%	0,00%	*0,00%*
	Α5	2,30%	0,00%	*0,00%*
	Α6	2,30%	75,00%	*1,73%*
Β	Β1	3,50%	100,00%	*3,50%*
	Β2	3,50%	100,00%	*3,50%*
	Β3	3,50%	0,00%	*0,00%*
	Β4	3,50%	90,00%	*3,15%*
Γ	Γ1	3,30%	100,00%	*3,30%*
	Γ2	3,30%	100,00%	*3,30%*
	Γ3	3,30%	100,00%	*3,30%*
	Γ4	3,30%	100,00%	*3,30%*
	Γ5	3,30%	75,00%	*2,48%*
	Γ6	3,30%	100,00%	*3,30%*
Δ	Δ1	0,50%	100,00%	*0,50%*
	Δ2	0,50%	90,00%	*0,45%*
	Δ3	0,50%	0,00%	*0,00%*
Ε	Ε1	0,50%	100,00%	*0,50%*
	Ε2	0,50%	100,00%	*0,50%*
	Ε3	0,50%	100,00%	*0,50%*
ΣΤ	ΣΤ1	2,67%	0,00%	*0,00%*
	ΣΤ2	2,67%	30,00%	*0,80%*
	ΣΤ3	2,67%	100,00%	*2,67%*
Ζ	Ζ1	3,50%	100,00%	*3,50%*
	Ζ2	3,50%	100,00%	*3,50%*
Η	Η1	3,50%	0,00%	*0,00%*
	Η2	3,50%	100,00%	*3,50%*

Στην υποκατηγορία Α6 (περιγραφή χλωρίδας και πανίδας) η ΠΠΕ δεν κάνει μια τυπική σύγκριση του οικοσυστήματος της περιοχής με αντίστοιχα οικοσυστήματα στην Ελλάδα. Στη υποκατηγορία Α2 (ανάλυση τρεχόντων επιπέδων μόλυνσης), σε κάποιες περιπτώσεις δεν έχουν γίνει ποσοτικές μετρήσεις των επιπέδων ρύπανσης και εκεί ο εκπονητής της μελέτης χρησιμοποιεί μόνο την υποκειμενική του κρίση. Στην υποκατηγορία Α2 (περιγραφή κοινωνικού περιβάλλοντος) η ΠΠΕ δεν δίνει μια ανάλυση των χρήσεων γης ούτε και κάποια εκτίμηση για τη μελλοντική διαμόρφωση των κοινωνικών χαρακτηριστικών της περιοχής. Στην υποκατηγορία Α4 δεν υπάρχει σε ολόκληρη την ΠΠΕ ούτε μία αναφορά για παρόμοια έργα στην περιοχή. Στην υποκατηγορία Α5 δεν αναλύεται καν η δυναμική του περιβάλλοντος σε περίπτωση απουσίας του έργου.

Στο κριτήριο Β3 έχει παραληφθεί εξ ολοκλήρου η ανάλυση του κύκλου ζωής του έργου. Στο κριτήριο Β4 (αιτιολόγηση αναγκαιότητας του έργου) η μόνη παράλειψη είναι η μη αναφορά στα επιχειρήματα υπέρ του έργου, η ασφάλεια των σπιτιών στην παράκτια ζώνη καθώς και η αισθητική βελτίωση της παραλίας.

Παρατηρήθηκαν συγκεκριμένες ελλείψεις σε ορισμένα κριτήρια αξιολόγησης στην ΠΠΕ του τεχνικού έργου για την αντιδιαβρωτική προστασία της παραλίας της Μεθώνης. Στο κριτήριο Γ5 (χρήση μοντέλων πρόβλεψης) το μειονέκτημα είναι ότι δεν παρατέθηκε και το μοντέλο πρόβλεψης που χρησιμοποιούν οι συγκοινωνιολόγοι για να εκτιμηθεί η αύξηση του κυκλοφοριακού φόρτου της περιοχής. Στο Δ2 (σαφήνεια των μέτρων) στο κομμάτι όπου περιγράφονται τα μέτρα για τη μείωση της ηχορρύπανσης, αναφέρονται μόνο οι υπάρχουσες νομοθετικές διατάξεις χωρίς κάποια περεταίρω επεξήγηση που θα έκανε το κείμενο εύληπτο και σε άτομα που δεν είναι ειδικευμένα σε δικανική ορολογία. Στο κριτήριο Δ3 δεν αναφέρεται πουθενά κάποια μέθοδος ελέγχου του επιπέδου των ρύπων, ειδικά κατά τη φάση λειτουργίας της κατασκευής.

Όσον αφορά το κριτήριο ΣΤ1 (έρευνα ρίσκου) η ΠΠΕ δεν κάνει καμία απολύτως αναφορά στις πιθανότητες αποτυχίας του έργου ούτε γίνεται κάποια ανάλυση κόστους – ωφέλους ή αναφορά σε τεχνικές αποτίμησης. Τέλος, στο κριτήριο Η1, δεν υπάρχουν προτάσεις για το πώς θα μπορούσε να συνεισφέρει το κοινό της περιοχής του έργου στην ανάπτυξη της ΠΠΕ. Συνολικά, αν αθροιστούν οι βαθμοί κάθε κριτηρίου, προκύπτει τελικός βαθμός ίσος με *65%*. Συνεπώς, η ΠΠΕ μπορεί να καταταχθεί στην κατηγορία της Μετρίως Επαρκούς μελέτης

4. Συμπεράσματα

Η δεκαετία 1993-2003 ήταν μια χρήσιμη περίοδος για την προσαρμογή της Ελλάδας στις ευρωπαϊκές πρακτικές των ΠΠΕ και ΜΠΕ. Ωστόσο, ένα μεγάλο ποσοστό των εξετασθέντων μελετών έχουν αποτύχει να αντιμετωπίσουν τα κρίσιμα ζητήματα της ΠΠΕ, παρά το γεγονός ότι όλες τους είχαν ακολουθήσει το νομικό πλαίσιο για τη δομή του φακέλου και οι αρμόδιες αρχές τελικά τις ενέκρινε.

Η εκπόνηση μελετών εκτίμησης των περιβαλλοντικών επιπτώσεων, καθώς και την έγκρισή τους από τις αρμόδιες αρχές είναι δύο περίπλοκες διαδικασίες. Η ανεπάρκεια όσον αφορά διεπιστημονικό χαρακτήρα των ομάδων μελέτης και των αρχών είναι ένα από τα θεμελιώδη προβλήματα στις διαδικασίες εκτίμησης των περιβαλλοντικών επιπτώσεων. Από τη μία πλευρά, οι ομάδες μελέτης ή/ και οι εταιρείες συμβούλων επιχειρήσεων αναλαμβάνουν κάθε κατηγορία έργου και όλα τα είδη των μελετών, χωρίς να είναι σε θέση να υποστηρίξουν την έρευνα για όλους τους κλάδους που απαιτούνται. Ως εκ τούτου, αυτές οι ομάδες δεν έχουν το κατάλληλο επιστημονικό υπόβαθρο για την αντιμετώπιση όλων των θεμάτων που αφορούν το περιβάλλον και τα τεχνικά χαρακτηριστικά του κάθε έργου. Ένας ενδεικτικός κατάλογος των εμπειρογνωμόνων που απαιτούνται για να συμμετάσχουν στην εκτίμηση των περιβαλλοντικών επιπτώσεων περιλαμβάνει όλους τους μηχανικούς (πολιτικούς, χημικούς, περιβαλλοντολόγους, κλπ.), βιολόγους, χημικούς, φυσικούς, επιστήμονες γεωργίας, κοινωνιολόγους, γεωλόγους, κλπ. Το τεχνικό έργο όσον αφορά το περιβάλλον σχετίζεται με ένα ευρύ πεδίο επιστημονικής γνώσης και εμπειρίας, και μόνο ένα μέρος αυτών των ζητημάτων μπορούν να αντιμετωπιστούν επαρκώς, αποκλειστικά από έναν από τους κλάδους που αναφέρονται.

Το ίδιο ισχύει και για τις αρμόδιες αρχές, όπου, στις περισσότερες περιπτώσεις, είναι αρκετά δύσκολο για το διαθέσιμο προσωπικό να χειριστεί το σύνολο των μελετών που υποβάλλονται με αξιοπιστία. Άλλη μία από τις πιο σημαντικές, αλλά και περίπλοκες πτυχές μιας περιβαλλοντικής διαδικασίας εκτίμησης επιπτώσεων, είναι ο προσδιορισμός των μέτρων ελέγχου για κάθε στάδιο του κύκλου ζωής του έργου. Δυστυχώς, τα μέτρα αυτά δεν αποτελούν κριτήριο για την έγκριση της περιβαλλοντικής μελέτης από τις αρμόδιες αρχές. Ως εκ τούτου, οι περισσότεροι ανάδοχοι μελετών, κυρίως λόγω του κόστους που συνδέεται με την εκτέλεση των μέτρων ελέγχου, δεν θεωρούν την παρακολούθηση ως αναπόσπαστο μέρος της διαδικασίας για την εξέταση της εξέλιξης των επιπτώσεων που επέφερε το έργο/ δραστηριότητα στο περιβάλλον.

Κάθε σχέδιο, κάθε περιοχή είναι μοναδική περίπτωση και θα πρέπει να αντιμετωπίζεται ως τέτοια. Ορισμένες γενικές απαιτήσεις, οι οποίες ισχύουν για την πλειοψηφία ενός συγκεκριμένου τύπου έργου, θα μπορούσαν να καθορίζονται από τη νομοθεσία. Οι απαιτήσεις αυτές θα πρέπει να αντιμετωπίζουν τα θέματα σχετικά με το περιβάλλον, το έργο, τις επιπτώσεις και τα μέτρα μετριασμού. Η πλήρης περιγραφή και προσδιορισμός αυτών των θεμάτων θεωρείται ανεκτίμητη. Όπως αναφέρθηκε στις προηγούμενες ενότητες, πολλές πτυχές παραλείπονται για διάφορα έργα, κάτι που καθιστά τη χρήση της κοινής λογικής και της χρήσης ποιοτικών κριτηρίων απαραίτητη .

Η πίεση χρόνου λόγω των δαπανών λειτουργίας και τα οφέλη που θα προκύψουν μετά την κατασκευή και λειτουργία του έργου οδηγεί σε επιτάχυνση των διαδικασιών που αφορούν τη διεξαγωγή της μελέτης , καθώς και την έγκρισή της. Το σκεπτικό της «τυφλής» τυποποίησης, δηλαδή ανεπαρκής επεξεργασία των δεδομένων, χρήση περιγραφών και χαρτών από άλλες μελέτες, μειώνει σημαντικά το χρόνο που απαιτείται για την κατάρτιση της ΠΠΕ. Η διάρκεια για την κατάρτιση μιας ΠΠΕ δεν είναι ίδια για όλα τα έργα , αλλά μάλλον εξαρτάται από το είδος και το μέγεθος του έργου, τα προσόντα, τις δεξιότητες και την προσπάθεια του ανάδοχου μελέτης για τη συλλογή και περιγραφή όλων χαρακτηριστικών του έργου και του περιβάλλοντός του. Επιπλέον, λόγω του μεγάλου αριθμού των μελετών που υποβάλλονται και το μικρό αριθμό των αναθεωρητών για την εξέτασή τους, ο χρόνος που διατίθεται για τον έλεγχο κάθε μελέτης είναι ελάχιστος.

Ως εκ τούτου, είναι απαραίτητη η τυποποιημένη χρήση μιας εμπεριστατωμένης μεθόδου κριτηρίων αξιολόγησης, όπως αυτή που προτείνεται από την παρούσα εργασία. Στο στάδιο αυτό μπορεί με ευκολία να χρησιμοποιηθεί για ΠΠΕ, αλλά υπάρχει και η δυνατότητα με κάποιες τροποποιήσεις και διασαφηνίσεις να εφαρμοστεί στο μέλλον ένα παρόμοιο σύστημα βαθμονόμησης και για οριστικές ΜΠΕ. Η διαδικασία αυτή ενώ δημιουργήθηκε για εκτίμηση επιπτώσεων από έργα ή δραστηριότητες, μπορεί να εφαρμοστεί και στη στρατηγική εκτίμηση επιπτώσεων από σχέδια η προγράμματα.

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«Σχέδιο αντιδιαβρωτικής προστασίας παραλίας δήμων Μεθώνης Αιπείας.» Προμελέτη Περιβαλλοντικών Επιπτώσεων Δήμου Μεθώνης, Αναπτυξιακή Μεσσηνίας Α.Ε.

Αξιοποίηση των αρχών της Βιομηχανικής Οικολογίας για την αποτίμηση της περιβαλλοντικής βιωσιμότητας επιχειρήσεων

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Περίληψη
Ο όρος της βιώσιμης ανάπτυξης συχνά χρησιμοποιείται από την βιομηχανία για να αποκρύψει δράσεις οι οποίες δεν είναι ούτε βιώσιμες αλλά ούτε και αναπτυξιακές. Στο πλαίσιο αυτό απαιτείται η ανάπτυξη ενός ενιαίου μεθοδολογικού πλαισίου αποτίμησης της βιωσιμότητας των βιομηχανικών δραστηριοτήτων. Στην συγκεκριμένη εργασία, αναλύθηκαν και επιλέχθηκαν τα στοιχεία εκείνα στα οποία μια βιομηχανία θα πρέπει να στοχεύει ώστε να βελτιώσει την περιβαλλοντική της βιωσιμότητα και κατά επέκταση χρίζουν αποτίμησης. Τα στοιχεία αυτά επιλέχθηκαν σύμφωνα με τις αρχές της Βιομηχανικής Οικολογίας η οποία χαρακτηρίζεται από πολλούς συγγραφείς ως η επιστήμη της βιωσιμότητας. Τα χαρακτηριστικά, οι αρχές και τα εργαλεία της Βιομηχανική Οικολογίας παρουσιάζονται αναλυτικά, υποδεικνύοντας την σημασία και την ικανότητά της να προωθεί και να υποστηρίζει καινοτόμες και δημιουργικές δράσεις όσον αφορά την βιώσιμη ανάπτυξη. Η ενσωμάτωση των αρχών σε ένα πλαίσιο αποτίμησης δύναται να πραγματοποιηθεί επιβραβεύοντας εκείνες τις βιομηχανίες οι οποίες με την λειτουργία τους, τις δράσεις τους και τις αποφάσεις τους, μετουσιώνουν τις προτάσεις της Βιομηχανικής Οικολογίας. Συγκεκριμένοι τρόποι προτείνονται για την επιτυχή ενσωμάτωση των αρχών ενώ αναπτύχθηκε μια εικόνα ενός ιδεατού βιώσιμου βιομηχανικού συστήματος βάσει του οποίου μπορεί να συγκριθεί η περιβαλλοντική βιωσιμότητα των υπολοίπων βιομηχανιών. Η υιοθέτηση συγκεκριμένων αρχών οι οποίες υποβάλλονται από ένα συγκεκριμένο και δομημένο πλαίσιο (π.χ. Βιομηχανική Οικολογία), ενισχύει την ποιότητα των αποτελεσμάτων σε σύγκριση με την επιλογή δεικτών και αξόνων αποτίμησης χωρίς συγκεκριμένη στρατηγική και σκοπό
Λέξεις κλειδιά: Βιομηχανία, περιβαλλοντική αξιολόγηση, βιώσιμη ανάπτυξη, μεθοδολογικό πλαίσιο.

Utilization of industrial economy principles for assessing the environmental systainability of industries

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Abstract
The basic characteristics in which industries should focus on for improving their environmental sustainability were analyzed and are presented in the specific study. The characteristics were chosen according to the principles of Industrial Ecology. The

integration of these principles into a sustainability assessment framework can be achieved by rewarding those industries whose operation, actions and decisions follow the proposed characteristics. Specific ways of integration are proposed whereas an ideal sustainable industrial system was developed which can be used as a benchmark standard of environmental sustainability for other industries. The adoption of certain principles which are defined by a specific and structured framework enhances the quality of assessment in contrast with selecting indicators and impact categories without specific strategy and purpose.

Keywords: Industry, environmental assessment, sustainable development, methodological framework.

1. Εισαγωγή

Η υιοθέτηση των αρχών της βιωσιμότητας απαιτεί από τον κλάδο της βιομηχανίας την εφαρμογή στρατηγικών οι οποίες αποδέχονται και κατανοούν την υπευθυνότητα της βιομηχανίας απέναντι στην κοινωνία και το περιβάλλον τόσο σε τοπικό όσο και σε παγκόσμιο επίπεδο (Labuschagne et al., 2005). Η επίτευξη της βιωσιμότητας για μια βιομηχανία εμπεριέχει την πρόκληση του να παρέχει ανταγωνιστικά αποτελέσματα και προϊόντα σε βραχυπρόθεσμο χρόνο, ενώ παράλληλα προσπαθεί να προστατεύσει, να διατηρήσει και να ενισχύσει τις ανθρωπογενείς και φυσικές πηγές μακροπρόθεσμα (Artiach et al., 2010).

Η περιβαλλοντική βιωσιμότητα ορίζεται ως «*η κατάσταση κατά την οποία ζωτικές περιβαλλοντικές λειτουργίες διασφαλίζονται για τις επόμενες γενεές*» (Hueting, 2010). Η πλειοψηφία των υφιστάμενων μεθοδολογιών επίτευξης και αποτίμησης της βιωσιμότητας αφορά στο περιβάλλον, ενώ αυτήν την στιγμή το περιβάλλον βρίσκεται στην πρώτη γραμμή της βιώσιμης ανάπτυξης. Η ενσωμάτωση θεμάτων που σχετίζονται με την περιβαλλοντική βιωσιμότητα στην ανάπτυξη προϊόντων και εν γένει στις επιχειρηματικές δραστηριότητες, παρουσιάζει σημαντικά οφέλη όπως είναι α) η αυξημένη αποδοτικότητα στην χρήση πόρων, β) οι αυξημένες πωλήσεις, γ) η είσοδος σε νέες αγορές, δ) η βελτίωση της εικόνας της επιχείρησης, ε) η διαφοροποίηση του προϊόντος σε σχέση με τον ανταγωνισμό, και στ) το ανταγωνιστικό πλεονέκτημα (Dangelico and Pujari, 2010). Παρόλα τα εμφανή πλεονεκτήματα της υιοθέτησης μιας βιώσιμης στρατηγικής, φαίνεται πως οι βιομηχανίες δεν έχουν κατανοήσει ουσιαστικά το μερίδιο ευθύνης τους αλλά και τις σημαντικές ευκαιρίες που προκύπτουν. Η πλειοψηφία των επιχειρήσεων προχωρεί σε περιβαλλοντικές επενδύσεις εξαιτίας των αρνητικών επιπτώσεων πιθανών οικολογικών ατυχημάτων και όχι λόγω της αναγνώρισης των πλεονεκτημάτων και της αυξημένης αποδοτικότητας που απορρέει από αυτές (Sarmento et al., 2005).

Ο όρος της βιώσιμης ανάπτυξης πολλές φορές χρησιμοποιείται για να αποκρύψει δράσεις οι οποίες δεν είναι ούτε βιώσιμες αλλά ούτε και αναπτυξιακές (Luke, 2005). Επιπλέον δεν θα πρέπει να αμελείται το γεγονός πως *«Η βιωσιμότητα αφορά την θετική αλλαγή και όχι απλά την ελαχιστοποίηση των αρνητικών επιπτώσεων»* (Pope et al. 2004). Όλα τα παραπάνω σε συνδυασμό με την σχετική ασάφεια των ορισμών της βιωσιμότητας, ενισχύουν την σημασία ανάπτυξης ενός ενιαίου και αντικειμενικού πλαισίου/διαδικασίας αποτίμησης της περιβαλλοντικής βιωσιμότητας των βιομηχανιών.

2. Αποτίμηση της βιωσιμότητας

Ένας απλός ορισμός της αποτίμησης της βιωσιμότητας είναι *«μια διεργασία που κατευθύνει την λήψη αποφάσεων προς την βιωσιμότητα»* (Hacking and Guthrie, 2008). Οι Devuyst et al. (2001) όρισαν την αποτίμηση της βιωσιμότητας ως *«ένα εργαλείο που βοηθάει αυτούς που λαμβάνουν αποφάσεις και χαράζουν πολιτικές, να αποφασίσουν ποιες ενέργειες θα πρέπει να ακολουθήσουν ή μη, σε μια προσπάθεια να κάνουν την κοινωνία πιο βιώσιμη»*. Όπως παρατηρείται και από τους συγκεκριμένου ορισμούς, η αποτίμηση της βιωσιμότητας εξελίσσεται επί το πλείστον ως εργαλείο λήψεως αποφάσεων (Pope et al. 2004).

Η αποτίμηση της βιωσιμότητας είναι μια ιδιαιτέρως πολύπλοκη διαδικασία εξαιτίας του μεγάλου εύρους των θεμάτων και της πολυπλοκότητας των συστημάτων με τα οποία καταπιάνεται. Όπως τονίζουν και οι Gasparatos et. al. (2008), *«η αποτίμηση της βιωσιμότητας αναλαμβάνει την δύσκολη δουλειά του να ανακαλύψει, να μελετήσει και να προτείνει λύσεις για ένα μεγάλο και ανομοιογενές σύνολο θεμάτων που απασχολούν τον εκάστοτε ενδιαφερόμενο και επεκτείνονται σε διαφορετικές χωρικές και χρονικές κλίμακες»*. Επιπλέον, η αποτίμηση της βιωσιμότητας δεν αφορά μόνο την αξιολόγηση της υφιστάμενης κατάστασης, αλλά και της προόδου που συντελείται προς την βιωσιμότητα και την προώθηση της επιθυμητής συμπεριφοράς (Becker, 2004).

Από την στιγμή που η επίτευξη της βιωσιμότητας έχει τεθεί ως πρωτεύον στόχος της σύγχρονης κοινωνίας, και αφορά το σύνολο των συστημάτων που «*δραστηριοποιούνται*» στον πλανήτη, η αποτίμηση του κατά πόσο κινούμαστε προς την βιωσιμότητα (και πόσο απέχουμε από την βιωσιμότητα) είναι θέμα μείζονος σημασίας. Ως εκ τούτου, *«το πλήθος των εργαλείων, μεθόδων και διαδικασιών αποτίμησης της βιωσιμότητας είναι της τάξεως των εκατοντάδων»* (Poveda and Lipsett, 2011). Ωστόσο, ο αριθμός αυτός μειώνεται αισθητά αν υπολογίσουμε μόνο τα εργαλεία που μπορούν να εφαρμοστούν στην βιομηχανία. Τα Ηνωμένα Έθνη και οι εθνικές κυβερνήσεις αποτέλεσαν τις κινητήριες δυνάμεις προώθησης της βιώσιμης ανάπτυξης και κατά συνέπεια, τα περισσότερα πλαίσια αποτίμησης της βιωσιμότητας στοχεύουν σε εθνικό και τοπικό επίπεδο, ενώ πολύ λιγότερη πρόοδος έχει σημειωθεί σε επίπεδο βιομηχανιών (Labuschagne et al., 2005).

Η ανάλυση των υφιστάμενων μεθόδων αποτίμησης της βιωσιμότητας που μπορούν να εφαρμοστούν από την βιομηχανία (47 διαφορετικές μέθοδοι αναλύθηκαν από τους συγγραφείς) υπέδειξε πως υπάρχει ακόμη σημαντικό ερευνητικό κενό στον τρόπο με τον οποίο αποτιμάται η βιωσιμότητά τους. Κάθε μέθοδος και ομάδα μεθόδων (κλασικές μέθοδοι, μέθοδοι ανάλυσης κύκλου ζωής, μέθοδοι βασιζόμενες σε δείκτες) εμφανίζει συγκεκριμένα πλεονεκτήματα και μειονεκτήματα που σχετίζονται με τα ιδιαίτερα χαρακτηριστικά τους. Μια μέθοδος αποτίμησης της βιωσιμότητας θα πρέπει να εμφανίζει τα εξής γενικά χαρακτηριστικά ώστε να καλύπτονται οι βασικές αδυναμίες που παρατηρήθηκαν:

- Να λαμβάνει υπόψη στην αποτίμηση τα ιδιαίτερα χωρικά χαρακτηριστικά του εξεταζόμενου βιομηχανικού συστήματος και να μπορεί να αποτιμά την εξέλιξη της βιωσιμότητας μέσα στον χρόνο.

- Να αξιολογεί την βιομηχανία τόσο από άποψη επίδοσης όσο και λογοδοσίας, καθώς το ένα δεν εγγυάται το άλλο. Επιπλέον απαιτείται η ταυτόχρονη θέσπιση οριακών τιμών ώστε να εκφράζεται το κατά πόσο κινείται η βιομηχανία σε βιώσιμα επίπεδα.
- Να διασφαλίζει μια επαρκή ισορροπία ανάμεσα στο επίπεδο πολυπλοκότητας και την κάλυψη βασικών θεμάτων βιωσιμότητας.
- Να τονίζει ξεκάθαρα και να ελαχιστοποιεί, τις παραδοχές και τις αδυναμίες οι οποίες προκύπτουν κατά την ανάπτυξή της.
- Να εμπεριέχει κλιμακωτά επίπεδα δυσκολίας εφαρμογής (και αντίστοιχη κλίμακα αξιολόγησης), προς εξυπηρέτηση τόσο των μικρομεσαίων όσο και των πολύ μεγάλων βιομηχανιών.

Η ιδανική μέθοδος αποτίμησης της βιωσιμότητας θα λάμβανε υπόψη όλες τις παραμέτρους συγχρόνως (Ness et al., 2007). Η ανάπτυξη μιας τέτοιας μεθόδου ωστόσο εμπεριέχει πολύ υψηλό βαθμό πολυπλοκότητας, που για την περίπτωση της βιομηχανίας μεταφράζεται σε υψηλό κόστος και χρόνο. Εναλλακτικά, η αξιολόγηση των υφιστάμενων μεθόδων υπέδειξε πως ο συνδυασμός των τεχνικών της ανάλυσης κύκλου ζωής και της θεωρίας δεικτών, καλύπτει την πλειοψηφία των παρατηρούμενων αδυναμιών. Επόμενο βήμα στην ανάπτυξη ενός ενιαίου πλαισίου αποτίμησης της περιβαλλοντικής βιωσιμότητας βιομηχανιών είναι η εύρεση των ιδιαίτερων χαρακτηριστικών και του θεωρητικού υποβάθρου (Βιομηχανική Οικολογία) πάνω στο οποίο θα βασιστεί το υπό ανάπτυξη μεθοδολογικό πλαίσιο.

3. Βιομηχανική Οικολογία

Η έννοια της Βιομηχανικής Οικολογίας έγινε γνωστή από τους Frosch και Gallopoulos το 1989, οι οποίοι υποστήριξαν πώς ένα εξιδανικευμένο βιομηχανικό οικοσύστημα θα έπρεπε να λειτουργεί ως «*ανάλογο*» ενός βιολογικού οικοσυστήματος. Πιο συγκεκριμένα, σε ένα *«οίκο-βιομηχανικό οικοσύστημα»* τα απόβλητα της μιας βιομηχανίας θα αξιοποιούνταν ως πρώτη ύλη για κάποια άλλη ώστε να μειώνεται η σπατάλη πόρων (τίποτα να μην πηγαίνει χαμένο - περίπτωση τροφικών αλυσίδων). Η προσπάθεια ανάπτυξης συνεργασιών για την ανταλλαγή απορριπτέων υλικών, αποτελούσε διαχρονικά βασικό χαρακτηριστικό περιόδων οικονομικής ανάπτυξης (Desrochers, 2002).

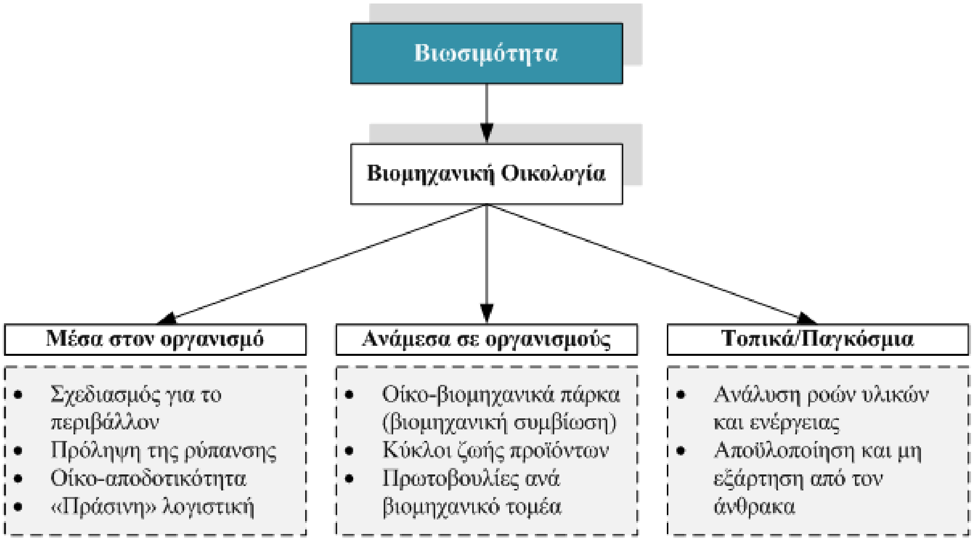
Το *«βιομηχανικό κομμάτι»* της Βιομηχανικής Οικολογίας έγκειται στην εστίασή της στον σχεδιασμό των προϊόντων και τις παραγωγικές διαδικασίες. Αντιλαμβάνεται τις βιομηχανίες ως βασικούς συντελεστές περιβαλλοντικής βελτίωσης λόγω της τεχνογνωσίας που κατέχουν. Το *«οικολογικό κομμάτι»* της Βιομηχανικής Οικολογίας έγκειται στην μελέτη των μη-ανθρώπινων φυσικών οικοσυστημάτων ως μοντέλα ιδεών για την βελτίωση των βιομηχανικών δραστηριοτήτων. Αντιλαμβάνεται την βιομηχανία ως μέρος ενός ευρύτερου οικοσυστήματος με το οποίο αλληλοεπηρεάζεται (Lifset and Graedel, 2002).

Η Βιομηχανική Οικολογία συνιστά μια πρακτική προσέγγιση στην βιωσιμότητα, δηλαδή προσπαθεί να απαντήσει στο ερώτημα κατά πόσο η βιώσιμη ανάπτυξη μπορεί να υπάρξει με έναν οικονομικά συμφέροντα τρόπο (Erkman, 2001). Η βασική διαφοροποίηση της Βιομηχανικής Οικολογίας έναντι των υπολοίπων πρωτοβουλιών και προσεγγίσεων που στοχεύουν στην βελτίωση της περιβαλλοντικής επίδοσης της βιομηχανίας (π.χ. πρόληψη της ρύπανσης, περιβαλλοντική διαχείριση ολικής ποιότητας κ.ά.) έγκειται στην ιδιαιτέρως ολιστική της προσέγγιση, στοχεύοντας σε θεμελιώδεις αλλαγές σε επίπεδο ευρύτερων συστημάτων και σε μακροπρόθεσμο χρονικό ορίζοντα (Lowe, 1993). Η Βιομηχανική Οικολογία δεν θα πρέπει να λογίζεται ως ένα αυστηρό περιβαλλοντικό εργαλείο το οποίο στοχεύει αποκλειστικά στην περιβαλλοντική επίδοση της βιομηχανίας. *«Εάν εφαρμοστεί σωστά, προωθεί την ανταγωνιστικότητα των επιχειρήσεων και την καινοτομία των παραγόμενων προϊόντων»* (Kapur and Graedel, 2004).

Ως νεοσύστατο πεδίο, η Βιομηχανική Οικολογία αποτελείται από διάφορες θεωρίες, εργαλεία και εφαρμογές. Κάποια από αυτά τα στοιχεία είναι επαρκώς ορισμένα και συνδέονται με τα υπόλοιπα, ενώ άλλα βρίσκονται σε πρώιμο ακόμη στάδιο ανάπτυξης χωρίς αυστηρή αλληλοσυσχέτιση μεταξύ τους (Lifset and Graedel, 2002). Στο Σχήμα 1 παρουσιάζονται τα βασικά στοιχεία της Βιομηχανικής Οικολογίας διαχωρισμένα βάσει του επιπέδου εφαρμογής τους (μέσα στην εταιρία, ανάμεσα σε εταιρίες και σε τοπική/παγκόσμια κλίμακα).

Ένας επιπλέον παράγοντας έκφρασης του δυναμικού της Βιομηχανικής Οικολογίας ως μέσο επίτευξης της βιωσιμότητας, είναι η σημαντική αποδοχή της από τα ανώτερα εκπαιδευτικά ιδρύματα για τον συγκεκριμένο σκοπό (Gaidajis et al., 2012; Gaidajis et al., 2012). Η Βιομηχανική Οικολογία απεδείχθη ιδιαιτέρως χρήσιμη για την διδασκαλία θεμάτων που σχετίζονται με την βιώσιμη ανάπτυξη σε μηχανικούς (Allenby et al., 2009) ενώ αποτελεί, όλο και περισσότερο, βασικό σημείο αναφοράς στα πανεπιστήμια διεθνώς (ISIE, 2010). Παρόλα αυτά, η Βιομηχανική Οικολογία δεν είναι υπεράνω κριτικής και υπάρχουν αρκετά εμπόδια για την αποδοχή της από τις βιομηχανίες με κυριότερο την αδυναμία υιοθέτησης των αρχών των φυσικών οικοσυστημάτων από τις βιομηχανικές δραστηριότητες.

Σχήμα 1: Τα στοιχεία της βιομηχανικής οικολογίας διαχωρισμένα βάσει του επιπέδου εφαρμογής τους (Αναπροσαρμοσμένο από: Lifset and Graedel, 2002).



4. Αρχές της Βιομηχανικής Οικολογίας

Το σύνολο των αρχών της Βιομηχανικής Οικολογία όπως αυτές διακρίνονται στην σχετική βιβλιογραφία αναλύεται στην συνέχεια (Garner and Keoleian, 1995; Andrews, 2001; Korhonen, 2001; Cohen, 2004; Deutz and Gibbs, 2004; Dewulf and Langenhove, 2005; OECD, 2009).

Βιώσιμη κατανάλωση πόρων και υλικών: Η πρόβλεψη σχετικά με την μελλοντική χρήση και την εξάντληση υλικών αποτελεί ένα σημαντικό σημείο προσοχής για την Βιομηχανική Οικολογία (Harper and Graedel, 2004) που έχει ως απώτερο σκοπό την υλική απεξάρτηση. Η υλική απεξάρτηση, αναφέρεται στην ποσοτική μείωση του όγκου υλικών που καταναλώνονται για να ικανοποιήσουν τις απαιτήσεις ενός χρήστη, ενώ διατηρείται η ποιότητα της παρεχόμενης υπηρεσίας (λειτουργική μονάδα) (Glavic and Lukman, 2007).

Βιώσιμη διαχείριση και εξοικονόμηση ενέργειας: Η επίτευξη της βιωσιμότητας απαιτεί την παροχή ενέργειας προς όλους, με μέγιστη αποδοτικότητα και ελάχιστο περιβαλλοντικό αντίκτυπο (Kapur and Graedel, 2004). Στην περίπτωση της βιομηχανίας απαιτείται η χρήση ενέργειας σε υψηλές θερμοκρασίες και για τον λόγο αυτό είναι απαραίτητη η υιοθέτηση μέτρων και τεχνικών μείωσης της κατανάλωσης και αύξησης της ενεργειακής αποδοτικότητας εντός των ορίων της. Παράλληλα η βιομηχανία θα πρέπει να στραφεί σε καθαρότερες μορφές ενέργειας λαμβάνοντας πάντα υπόψη τις ιδιαιτερότητες της περιοχής στην οποία δραστηριοποιείται.

Ελαχιστοποίηση των αποβλήτων: Η ελαχιστοποίηση των αποβλήτων ορίζεται ως «*μέτρα ή τεχνικές που μειώνουν την ποσότητα των αποβλήτων που παράγονται κατά τις βιομηχανικές παραγωγικές διαδικασίες*» (Glavic and Lukman, 2007). Μια από τις βασικές αρχές της Βιομηχανικής Οικολογίας είναι πώς αντί να διαχειριζόμαστε τα απόβλητα, είναι καλύτερο να μην τα δημιουργούμε καθόλου (Munier, 2005). Ιδιαίτερα σημαντική για την Βιομηχανική Οικολογία είναι και η αναγνώριση των ροών αποβλήτων οι οποίες εμπεριέχουν υψηλή οικονομική αξία.

Ανάπτυξη συνεργασιών: Μία επιπλέον αρχή της Βιομηχανικής Οικολογίας είναι πως καμία επιχείρηση δεν μπορεί να είναι απόλυτα βιώσιμη από μόνη της (OECD, 2009). Οι βιομηχανίες θα πρέπει να μην δίνουν έμφαση αποκλειστικά στο προϊόν, και να αναπτύσσουν συνεργασίες για να εξασφαλίζουν την μέγιστη διαχείριση πόρων.

Προώθηση της εντοπιότητας: Η προώθηση της εντοπιότητας στα βιομηχανικά συστήματα οφείλεται στα πλεονεκτήματα που απορρέουν από την υιοθέτηση μιας στρατηγικής, σύμφωνα με την οποία οι βιομηχανίες επιλέγουν προμηθευτές και συνεργάτες οι οποίοι δραστηριοποιούνται σε κοντινή απόσταση. Δύο βασικά πλεονεκτήματα απορρέουν από την συγκεκριμένη επιλογή: α) σημαντικά περιβαλλοντικά οφέλη λόγω της μείωσης των μεταφορών και κατά συνέπεια των έμμεσων εκπομπών που απορρέουν από αυτές και β) μείωση του κινδύνου ατυχήματος κατά την διάρκεια της μεταφοράς.

Τεχνολογική πρόοδος και αποδοτικότητα διεργασιών: Βασική αρχή της Βιομηχανικής Οικολογίας είναι η κατανόηση της σημασίας της τεχνολογικής προόδου με την πάροδο του χρόνου – *«η συνειδητοποίηση ότι, καθώς η κοινωνία προοδεύει τεχνολογικά, κτίζει επάνω στην προηγούμενη τεχνολογική της βάση και επομένως δεν μπορεί να διατηρηθεί ή να βελτιωθεί χωρίς ισχυρή εξάρτηση από την τεχνολογία»* (Graedel and Allenby, 2009).

Ιδιαιτέρως σημαντική για την επίτευξη της περιβαλλοντικής βιωσιμότητας είναι η ανάπτυξη και η χρήση «έξυπνων» υλικών και συστημάτων τα οποία προσαρμόζονται στο περιβάλλον τους (π.χ. χρήση αυτοματισμών και αισθητηρίων).

Επανάχρηση και ανακύκλωση: Ένας από τους βασικούς στόχους της Βιομηχανικής Οικολογίας είναι να εξασφαλίσει την συνέχιση της χρήσεως ενός προϊόντος/υλικού και μετά το τέλος ζωής του μέσω της επανάχρησής του είτε με την αξιοποίηση μερών του ως πρώτη ύλη ή για την παραγωγή ενέργειας (Cohen, 2004). Σε περίπτωση που δεν είναι δυνατή η επαναχρησιμοποίηση ενός προϊόντος/υλικού, η βιομηχανία πρέπει να επιδιώξει, εάν είναι δυνατόν, την ανακύκλωσή του. Βασικός παράγοντας επιτυχίας της ανακύκλωσης για την Βιομηχανική Οικολογία είναι η διεύρυνση του φάσματος των υλικών που μπορούν να ανακυκλωθούν και σε υλικά που μπορούν να επαναχρησιμοποιηθούν στο φυσικό περιβάλλον (OECD, 2009).

Προώθηση της περιβαλλοντικής αμεροληψίας: Η βιομηχανία θα πρέπει να πείθει για την ειλικρινή της δέσμευση μείωσης των επιπτώσεών της στο περιβάλλον και αύξησης της περιβαλλοντικής της βιωσιμότητας και την αντικειμενικότητα των αποφάσεών της. Η ύπαρξη ενός αξιόπιστου ελεγκτικού μηχανισμού ή ενός τρίτου αντικειμενικού φορέα-κριτή για την αξιολόγηση της περιβαλλοντικής της βιωσιμότητας, αναμένεται να ενισχύσει την αποδοχή των δράσεων της βιομηχανίας από τοπικούς φορείς, την κοινωνία κ.λπ.

Ενσωμάτωση της ανάλυσης κύκλου ζωής: Η ενσωμάτωση των αρχών της ανάλυσης κύκλου ζωής στην αξιολόγηση της βιωσιμότητας είναι αναπόφευκτη ώστε να επιτευχθούν αξιόπιστα αποτελέσματα (Dangelico and Pujari, 2010; Finkbeiner et al,. 2010). Η Βιομηχανική Οικολογία τονίζει την σημασία υιοθέτησης της ανάλυσης κύκλου ζωής στην λήψη αποφάσεων και την αποτίμηση των βιομηχανικών δραστηριοτήτων.

Διατήρηση της οικολογικής και ανθρώπινης υγείας: Η διατήρηση της οικολογικής και ανθρώπινης υγείας αποτελεί βασική αρχή της Βιομηχανικής Οικολογίας και εν γένει της βιώσιμης ανάπτυξης. Η βιομηχανία θα πρέπει να αξιολογεί την επίπτωσή της όχι μόνο σε υφιστάμενα προβλήματα τοπικού ενδιαφέροντος, αλλά και σε ζητήματα παγκόσμιου ενδιαφέροντος με μεγάλους χρόνους εμφάνισης συμπτωμάτων.

Στην συνέχεια, θα περιγραφεί ο τρόπος με τον οποίο οι αρχές που αναφέρθηκαν, δύναται να ενσωματωθούν στο προς ανάπτυξη μεθοδολογικό πλαίσιο, ενισχύοντας με αυτόν τον τρόπο την ποιότητα της αποτίμησης.

5. Ανάπτυξη πλαισίου αποτίμησης

Η αποτίμηση της βιωσιμότητας θα πρέπει να βασίζεται πάνω σε συγκεκριμένες αρχές (Pope et al., 2004), ώστε να ενισχύεται η αποτελεσματικότητα της. Η Βιομηχανικής Οικολογία επιλέχθηκε λόγω της ικανότητάς της να αποτιμά και να αναδεικνύει δράσεις που στοχεύουν στην βιωσιμότητα. Η ενσωμάτωση των αρχών στο πλαίσιο αποτίμησης θα πραγματοποιηθεί επιβραβεύοντας εκείνες τις βιομηχανίες (με την χρήση σχετικών δεικτών) οι οποίες με την λειτουργία τους, τις δράσεις τους και τις αποφάσεις τους, εφαρμόζουν τις προτάσεις της Βιομηχανικής Οικολογίας. Στον Πίνακα 1 παρουσιάζονται οι τρόποι ενσωμάτωσης κάθε αρχής στο μεθοδολογικό πλαίσιο.

Η ανάπτυξη του μεθοδολογικού πλαισίου σύμφωνα με ένα πρότυπο βιώσιμο βιομηχανικό σύστημα, επιλύει μερικώς ένα από τα μεγαλύτερα προβλήματα των σχετικών μεθόδων αποτίμησης, αυτό της μη ενσωμάτωσης της λογικής της «απόστασης από τον στόχο». Οι περισσότερες μέθοδοι αποτίμησης στοχεύουν στην αποτίμηση της υφιστάμενης κατάστασης η οποία, σε σύγκριση με παλαιότερες ή μελλοντικές επιδόσεις, δίνει μια εικόνα της βελτίωσης ή μη της βιομηχανίας, χωρίς ωστόσο να εκφράζεται απαραίτητα η πραγματική απόσταση από την πραγματικά βιώσιμη επίδοση. Θέτοντας ως βέλτιστη βαθμολογία ένα ιδεατό βιώσιμο βιομηχανικό σύστημα, η βιομηχανία γνωρίζει έμμεσα την πραγματική της επίδοση όσον αφορά την περιβαλλοντική της βιωσιμότητα.

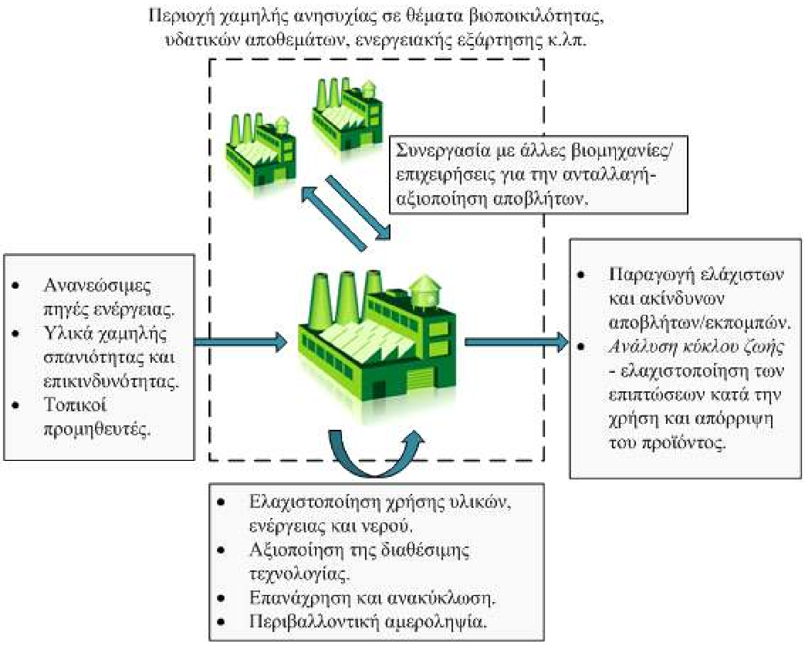
Πίνακας 1: Τρόποι ενσωμάτωσης των αρχών της Βιομηχανικής Οικολογίας στο πλαίσιο αποτίμησης της περιβαλλοντικής βιωσιμότητας.

Αρχή	Τρόπος ενσωμάτωσης στο πλαίσιο
Βιώσιμη κατανάλωση πόρων και υλικών	Επιβράβευση της μείωσης της χρήσης υλικών και πρώτων υλών. Επιβράβευση της χρήσης υλικών και πρώτων υλών χαμηλής σπανιότητας.
Βιώσιμη διαχείριση και εξοικονόμηση ενέργειας	Επιβράβευση της μείωσης της κατανάλωσης ενέργειας. Επιβράβευση της αύξησης του ποσοστού χρήσεως ενέργειας που προέρχεται από καθαρότερες πηγές.
Ελαχιστοποίηση των αποβλήτων	Επιβράβευση της μείωσης εκπομπών και αποβλήτων. Επιβράβευση της ύπαρξης αποδοτικών συστημάτων διαχείρισης και απόρριψης αποβλήτων.
Ανάπτυξη συνεργασιών	Επιβράβευση της ανάπτυξης συνεργασιών ανταλλαγής αποβλήτων με άλλες βιομηχανίες και εταιρίες διαχείρισης αποβλήτων/ανακύκλωσης. Επιβράβευση ανάπτυξης συνεργασιών με άλλους φορείς (π.χ. Δήμοι, Πανεπιστήμια) για την προώθηση της καινοτομίας.
Προώθηση της εντοπιότητας	Επιβράβευση μείωσης των συνολικών διανυθέντων χιλιομέτρων που απαιτούνται για την προμήθεια των απαραίτητων πρώτων υλών και εξοπλισμού.
Τεχνολογική πρόοδος και αποδοτικότητα διεργασιών	Επιβράβευση της χρήσεως τεχνολογιών εξοικονόμησης ενέργειας, νερού και υλικών (π.χ. αισθητήρες). Επιβράβευση της χρήσεως βέλτιστων διαθέσιμων τεχνικών.
Επανάχρηση και ανακύκλωση	Επιβράβευση επανάχρησης προϊόντων, τμημάτων του προϊόντος, υλικών και νερού. Επιβράβευση χρήσεως υλικών που προέρχονται από ανακύκλωση.
Προώθηση της περιβαλλοντικής αμεροληψίας	Επιβράβευση της ύπαρξης περιβαλλοντικών πιστοποιήσεων από ανεξάρτητους φορείς. Επιβράβευση της ύπαρξης συστήματος περιβαλλοντικής διαχείρισης.
Ενσωμάτωση της ανάλυσης κύκλου ζωής	Ανάλυση των επιπτώσεων της βιομηχανίας λαμβάνοντας υπόψη τον κύκλο ζωής των συστημάτων που εξετάζονται.
Διατήρηση της οικολογικής και ανθρώπινης υγείας	Επιβράβευση της χρήσης υλικών χαμηλής επικινδυνότητας. Εξέταση και ποσοτικοποίηση της συνεισφοράς της βιομηχανίας στα κρίσιμα περιβαλλοντικά ζητήματα.

Η προσπάθεια υιοθέτησης και τήρησης των αρχών της Βιομηχανικής Οικολογίας από μια βιομηχανία δίνει μια γενική εικόνα της *«ιδεατής»* βιομηχανίας από άποψη περιβαλλοντικής βιωσιμότητας (Σχήμα 2). Με άλλα λόγια, μια μέθοδος η οποία αποτιμά την περιβαλλοντική βιωσιμότητα σύμφωνα με τις αρχές της Βιομηχανικής Οικολογίας, θα έδινε στο εν λόγω βιομηχανικό σύστημα την μέγιστη δυνατή βαθμολογία.

Ένα επιπλέον βασικό σημείο προσοχής, είναι η εστίαση του μεθοδολογικού πλαισίου. Πολλές βιομηχανίες αποτιμούν την βιωσιμότητά τους μέσω της επίδοσης του προϊόντος που παράγουν. Η συγκεκριμένη προσέγγιση προσφέρει ιδιαιτέρως χρήσιμα συμπεράσματα για την βιομηχανία, εμπεριέχει ωστόσο το ρίσκο παράληψης παραγόντων οι οποίοι είναι ιδιαιτέρως επιβαρυντικοί για την περιβαλλοντικής βιωσιμότητα της βιομηχανίας (π.χ. ροή υλικών και ενέργειας για την λειτουργία των γραφείων της). Σύμφωνα με μελέτες, περίπου το 80% του περιβαλλοντικού κόστους ενός προϊόντος καθορίζεται στο στάδιο της σχεδίασης και κατά συνέπεια μετέπειτα προσπάθειες για τη βελτίωση του προϊόντος (π.χ. κατά την παραγωγή) αναμένεται να έχουν σχετικά χαμηλά αποτελέσματα (Graedel and Allenby, 2009). Ως εκ τούτου η αποτίμηση της βιωσιμότητας μέσω της περιβαλλοντικής βιωσιμότητας αποκλειστικά του προϊόντος, ενδέχεται να μην αφήσει ιδιαιτέρως πολλά περιθώρια στην διοίκηση για να προβεί σε βελτιωτικές κινήσεις.

Σχήμα 2: Το «Βιώσιμο» βιομηχανικό σύστημα σύμφωνα με τις αρχές της Βιομηχανικής Οικολογίας.



6. Συμπεράσματα

Στην παρούσα εργασία υποδείχθηκαν τα γενικά χαρακτηριστικά τα οποία θα πρέπει να έχει ένα μεθοδολογικό πλαίσιο αποτίμησης της περιβαλλοντικής βιωσιμότητας ώστε να καλύπτει τις βασικές αδυναμίες των υφιστάμενων μεθόδων. Επιπλέον επιλέχθηκαν και αναλύθηκαν τα στοιχεία εκείνα στα οποία μια βιομηχανία θα πρέπει να στοχεύει ώστε να βελτιώσει την περιβαλλοντική της βιωσιμότητα και κατά επέκταση χρίζουν αποτίμησης. Τα χαρακτηριστικά, οι αρχές και τα εργαλεία της Βιομηχανική

Οικολογίας εκτιμάται ότι είναι ιδιαιτέρως χρήσιμα στην προώθηση βιώσιμων στρατηγικών, υποδεικνύοντας την σημασία και την ικανότητά της να προωθεί και να υποστηρίζει καινοτόμες και δημιουργικές δράσεις όσον αφορά την βιώσιμη ανάπτυξη.

Επόμενος στόχος των συγγραφέων είναι η ανάπτυξη ενός τελικού μεθοδολογικού πλαίσιο αποτίμησης της περιβαλλοντικής βιωσιμότητας βιομηχανιών λαμβάνοντας υπόψη τα χαρακτηριστικά που αναλύθηκαν προηγουμένως. Το συγκεκριμένο πλαίσιο θα μπορεί να εφαρμοστεί από όλες τις βιομηχανίες και θα αποτιμά με αξιόπιστο και αποτελεσματικό τρόπο την περιβαλλοντική τους βιωσιμότητα στον χώρο και τον χρόνο.

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Προς μία στρατηγική προσαρμογής στην Κλιματική Αλλαγή: Ο ρόλος της εκτίμησης περιβαλλοντικών επιπτώσεων

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Περίληψη

Η αναγνώριση, από τη διεθνή κοινότητα πως τα προληπτικά μέτρα δεν είναι πλέον αρκετά να ανατρέψουν την εξέλιξη του φαινομένου της μεταβολής του κλίματος, οδήγησε στη σταδιακή διαμόρφωση στρατηγικών άμβλυνσης των πιθανών επιπτώσεών του. Η Ευρωπαϊκή Ένωση με την έκδοση της Λευκής Βίβλου «Η προσαρμογή στην αλλαγή του κλίματος: προς ένα ευρωπαϊκό πλαίσιο δράσης» (2009) υπογράμμισε αυτή την ανάγκη, καλώντας τα κράτη-μέλη να εκπονήσουν αντίστοιχα Εθνικά Σχέδια. Η Ελλάδα, παρόλο που χαρακτηρίζεται ιδιαίτερα ευάλωτη λόγω της γεωγραφικής της θέσης και της εκτεταμένης ακτογραμμής της όσο αφορά στην κλιματική αλλαγή, δεν έχει ολοκληρώσει ακόμη την εκπόνηση μιας τέτοιας στρατηγικής προσαρμογής. Η παρούσα εργασία επιδιώκει να συμβάλλει στην τρέχουσα διαδικασία προτείνοντας τη Στρατηγική Εκτίμηση Περιβαλλοντικών Επιπτώσεων (ΣΜΠΕ) ως εργαλείο ικανό να διαχειριστεί, τόσο την ουσία της κατάλληλης προσαρμογής του σχεδιασμού του ελληνικού χώρου, όσο και την αναγκαία ανάπτυξη συνεργασίας μεταξύ των επιστημονικών κλάδων που εμπλέκονται σε ένα τέτοιο πολυσύνθετο πρόβλημα. Παράλληλα, επιζητείται η εκτίμηση της αποτελεσματικότητας της μεθόδου (με κατάλληλη αναδιαμόρφωσή της) στην περίπτωση εφαρμογής της με τα έως τώρα δεδομένα Προς αυτή την κατεύθυνση, εντοπίζονται αναλογίες ανάμεσα στα χαρακτηριστικά του προβλήματος της μεταβολής του κλίματος και στους διαχειριστικούς στόχους της ΣΜΠΕ, χρησιμοποιώντας ως κοινή γλώσσα αναφοράς αυτή των πολύπλοκων συστημάτων. Μέσα από αυτή την ανάλυση η ΣΜΠΕ επαναπροσδιορίζεται, αντλώντας από τις έννοιες της ανθεκτικότητας (resilience), της προσαρμοστικής διαχείρισης (adaptive management) και της πολυπλοκότητας (complexity). Το μεθοδολογικό πλαίσιο που προκύπτει εκσυγχρονίζει τον θεσμό των ΣΜΠΕ, έτσι όπως αυτός είναι αντιληπτός στον ελληνικό χώρο. Ταυτόχρονα, συνεισφέρει σε προηγούμενες αντίστοιχες κατευθύνσεις της Ευρωπαϊκής Ένωσης, περί ενσωμάτωσης της κλιματικής αλλαγής στις μεθοδολογίες εκτίμησης επιπτώσεων.

Λέξεις κλειδιά: Κλιματική αλλαγή, εκτίμηση επιπτώσεων, ανθεκτικότητα, προσαρμοστική διαχείριση, πολυπλοκότητα.

JEL Κωδικοί: Q5, Q54.

1. Εισαγωγή

Η αναγνώριση, από τη διεθνή κοινότητα πως τα προληπτικά μέτρα δεν είναι πλέον αρκετά να ανατρέψουν την εξέλιξη του φαινομένου της μεταβολής του κλίματος, οδήγησε στη σταδιακή διαμόρφωση στρατηγικών άμβλυνσης των πιθανών επιπτώσεών του. Η Ευρωπαϊκή Ένωση με την έκδοση της Λευκής Βίβλου «Η προσαρμογή στην αλλαγή του κλίματος: προς ένα ευρωπαϊκό πλαίσιο δράσης» (2009) υπογράμμισε αυτή την ανάγκη, καλώντας τα κράτη-μέλη να εκπονήσουν αντίστοιχα Εθνικά Σχέδια. Η Ελλάδα, παρόλο που χαρακτηρίζεται ιδιαίτερα ευάλωτη, όσο αφορά στην κλιματική αλλαγή, λόγω της γεωγραφικής της θέσης και της εκτεταμένης ακτογραμμής της, δεν έχει ολοκληρώσει ακόμη την εκπόνηση μιας τέτοιας στρατηγικής προσαρμογής. Η παρούσα εργασία επιχειρεί να συμβάλλει στην τρέχουσα διαδικασία, αξιοποιώντας τη σύγχρονη επιστημονική γνώση για τα χαρακτηριστικά της κλιματικής αλλαγής και τις ανάγκες προσαρμογής στις επιπτώσεις της. Μέσα από βασικές πτυχές αυτής της γνώσης (πολυπλοκότητα, ανθεκτικότητα, προσαρμοστική διαχείριση), οι Στρατηγικές Μελέτες Περιβαλλοντικών Επιπτώσεων αναδιαμορφώνονται κατάλληλα και τελικά προτείνονται ως κύρια διαχειριστικά εργαλεία εφαρμογής του αναμενόμενου Εθνικού Σχεδίου Στρατηγικής.

2. Η κλιματική αλλαγή ως πολύπλοκο πρόβλημα

Σύμφωνα με τη Σύμβαση Πλαίσιο των Ηνωμένων Εθνών για την Κλιματική Αλλαγή (United Nations Framework Convention on Climate Change-UNFCCC), η κλιματική αλλαγή αφορά στη μεταβολή του κλίματος, που αποδίδεται άμεσα ή έμμεσα σε ανθρώπινη δραστηριότητα, η οποία μεταβάλλει τη σύνθεση της ατμόσφαιρας του πλανήτη και λειτουργεί προσθετικά στις φυσικές κλιματικές διακυμάνσεις. Η Διακυβερνητική Επιτροπή για την Κλιματική Αλλαγή (Intergovernmental Panel on Climate Change-IPCC) ορίζει την κλιματική αλλαγή, ως την παρατεταμένης περιόδου (δεκαετίας ή και περισσότερο) μεταβολή του κλίματος, που μπορεί να προσδιοριστεί από αλλαγές στη μέση κατάσταση ή/και στη διακύμανση των χαρακτηριστικών του. Αναφέρεται σε οποιαδήποτε αλλαγή του κλίματος, είτε λόγω μιας φυσικής μεταβλητότητας, είτε λόγω της ανθρώπινης δραστηριότητας (IPCC, 2007). Αυτόν τον δεύτερο ορισμό υιοθετεί η παρούσα εργασία, η οποία αντιλαμβάνεται το θέμα της διαχείρισης των επιπτώσεων των μεταβολών του κλίματος ως μια χρόνια, φυσική περιβαλλοντική δραστηριότητα, που προϋπήρχε της συζήτησης περί «κλιματικής αλλαγής», και επιβαρύνθηκε από τις ανθρώπινες επεμβάσεις στον πλανήτη.

Παρ' όλες τις διαφορετικές προσεγγίσεις, είναι κοινά αποδεκτό ότι το πρόβλημα της κλιματικής αλλαγής αποτελεί μια πολύπλοκη διαδικασία, η οποία διαμορφώνεται από ένα πλήθος αλληλεπιδράσεων μεταξύ κοινωνικο-οικονομικών, βιολογικών και ατμοσφαιρικών συστημάτων και χαρακτηρίζεται από μεγάλο βαθμό αβεβαιότητας ως προς τα δυνητικά της αποτελέσματα (Quiggin, 2007). Η βιβλιογραφία συγκλίνει στον χαρακτηρισμό του προβλήματος ως «δυσεπίλυτο» ή, πιο συχνά, «πολύπλοκο», αναφερόμενη σε μια δυναμική, συνεχώς εξελισσόμενη, μη γραμμική διαδικασία, που είναι δύσκολο να προβλεφθεί και να υποστεί διαχείριση μέσω μιας παραδοσιακής γραμμικής, αναλυτικής μεθόδου (Quiggin, 2007; EC, 2013; Roggema, 2013). Το «φαινόμενο της πεταλούδας» (Butterfly effect) που περιγράφηκε από τον μαθηματικό-μετεωρολόγο Lorenz (1963) και σύμφωνα με το οποίο το φτερούγισμα μιας πεταλούδας σε μια περιοχή είναι ικανό να δράσει καταλυτικά για την πρόκληση τυφώνα σε μια άλλη, απομακρυσμένη περιοχή, είναι ίσως η πιο δημοφιλής μεταφορά που χρησιμοποιείται για να περιγράψει την πολυπλοκότητα των καιρικών και συνεπώς κλιματικών συνθηκών (Roggema, 2012). Η ευαισθησία του αποτελέσματος στις αρχικές συνθήκες υπό τις οποίες αυτό δημιουργήθηκε, η μη γραμμικότητα μεταξύ αιτίου και αιτιατού, οι αναδυόμενες συμπεριφορές κ.α., αποτελούν μερικά μόνο από τα χαρακτηριστικά του πολύπλοκου προβλήματος της κλιματικής αλλαγής.

Ο χαρακτηρισμός της κλιματικής αλλαγής ως πολύπλοκη διαδικασία ή ως πολύπλοκο σύστημα (=σύστημα που έχει την ικανότητα να αναδιαμορφώνει τον εαυτό του με τρόπους οι οποίοι μπορεί να προκαλούν έκπληξη, να είναι δηλαδή δύσκολα προβλέψιμοι), δεν είναι τυχαία (Allen, 2012). Η έννοια της πολυπλοκότητας εμφανίστηκε ως μια νέα προσέγγιση, όταν έγινε κατανοητό ότι μέθοδοι που χρησιμοποιήθηκαν από τον Γαλιλαίο, τον Νεύτωνα, τον Laplace και άλλους, παρέχουν μια περιορισμένη δυνατότητα διαχείρισης των προβλημάτων που καλούνται να αντιμετωπίσουν οι διάφορες επιστήμες και κυρίως δεν είναι σε θέση να παρέχουν λογικές εξηγήσεις για έναν μεγάλο αριθμό φαινομένων (Baggio, 2008).

Ο επιστημονικός κόσμος έχει αναγνωρίσει πως οι ντετερμινιστικές και αναγωγιστικές αναλύσεις, αν και παραμένουν εφαρμόσιμες σε φαινόμενα που χαρακτηρίζονται από σταθερά συστήματα και γραμμικότητα, δεν είναι σε θέση να εξηγήσουν την αληθινή φύση για πολλά συστήματα που είναι λιγότερο σταθερά και μη γραμμικά. Με βάση επιστημονικά ευρήματα πιστεύεται σήμερα με αρκετή βεβαιότητα, ότι σχεδόν όλα τα φυσικά και κοινωνικά συστήματα είναι αλληλοεξαρτώμενα, μη γραμμικά, πολύπλοκα προσαρμοστικά συστήματα, συχνά γνωστά ως «κοινωνικό-οικολογικά συστήματα», τα οποία ορίζονται ως συστήματα που περιλαμβάνουν κοινωνικά (ανθρώπινα) και οικολογικά (βιοφυσικά) υποσυστήματα σε αμοιβαία αλληλεπίδραση (πχ. ένα τροπικό δάσος, μια επιχείρηση, μια κοινωνία, το ανοσοποιητικό σύστημα, το World Wide Web και η ταχεία παγκοσμιοποίηση της οικονομίας) (Waldrop 1992; Sanders et al., 2003). Η επιστήμη αναζητεί και έχει ήδη εντοπίσει πρότυπα συμπεριφοράς μέσα στο πολυσύνθετο χαρακτήρα και στις μεταξύ σχέσεις των συστημάτων που μελετά, στοχεύοντάς στην κατανόηση των διεργασιών τους, στην πρόβλεψη της μελλοντικής τους εξέλιξης και στην κατάλληλη διαχείρισή τους. Πρόκληση παραμένει η απόδοση των σύγχρονων επιστημονικών γνώσεων περί πολύπλοκων προβλημάτων, όπως είναι η κλιματική αλλαγή, σε πολιτικά πλαίσια, στρατηγικά σχέδια και διαχειριστικά εργαλεία, κάτι που σήμερα έως ένα βαθμό πραγματοποιείται μέσω της συζήτησης περί ανθεκτικότητας και ανάγκης για μια προσαρμοστική διαχείριση.

3. Από την αειφορία στην ανθεκτικότητα

Παρόλο που η αποδοχή της πολυπλοκότητας εντοπίζεται στη βιβλιογραφία ήδη από τη δεκαετία του ’60 (Castellani, 2013), μόνο πρόσφατα απέκτησε δυναμική εκτός της επιστημονικής κοινότητας και εισχώρησε στο λεξιλόγιο της λήψης αποφάσεων. Η ταυτόχρονη ανθρωπιστική, περιβαλλοντική και οικονομική κρίση των τελευταίων δεκαετιών έχει αυξήσει την αίσθηση της τρωτότητας και την αντίληψη ότι οι διαδικασίες, που σχετίζονται με την παγκοσμιοποίηση κάνουν του τόπους πιο ευάλωτους στις συνέπειες διεργασιών που παλιότερα θεωρούνταν «εξωτερικές» και άρα λιγότερο σημαντικές (Portugali, 2012). Ταυτόχρονα, η συνεχώς εξελισσόμενη τεχνολογία αλλάζει τον τρόπο αντίληψης και οίκησης του χώρου (ανθρώπινη κινητικότητα, σύγχυση γεωγραφικών συνόρων, γεωγραφία κυβερνοχώρου, διαδικτυακοί χάρτες κλπ.), προσφέροντας παράλληλα νέες δυνατότητες διαχείρισης αυτού και των προβλημάτων που περικλείει (Sanders et al., 2003). Υπό αυτές τις συνθήκες, βασικές έννοιες-πλαίσια, όπως αυτή της αειφορίας, που διατρέχουν επιστημονικές εισηγήσεις και εθνικά, ευρωπαϊκά και διεθνή πολιτικά κείμενα αναθεωρούνται και αναδιαμορφώνονται, ώστε να συγχρονιστούν με τις εξελίξεις.

Ιδιαίτερα σημαντική συμβολή στην περιγραφή της σχέσης αειφορίας-πολυπλοκότητας είναι αυτή του International Institute of Sustainable Development (IISD), το οποίο σύμφωνα με έρευνα της GlobeScan για το 2004, αναδείχθηκε ως το ερευνητικό κέντρο με τη μεγαλύτερη επιρροή στα ζητήματα της αειφόρου ανάπτυξης. Στην έκθεση «Indicators for Sustainable Development: Theory, Methods, Applications» (IISD, 1999) το IISD προσεγγίζει μια ιδιαίτερα συνηθισμένη πρακτική, που εστιάζει στη διαμόρφωση κατάλληλων δεικτών, με μια λιγότερο συνηθισμένη μεθοδολογία, η οποία βασίζεται εξαρχής στην θεωρία της πολυπλοκότητας. Η αειφόρος ανάπτυξη αντιμετωπίζεται ως συν-εξέλιξη πολύπλοκων φυσικών και κοινωνικών συστημάτων, τα οποία χαρακτηρίζονται από ιδιότητες όπως μη-γραμμικότητα, προσαρμοστικότητα και αυτο-οργάνωση. Η αειφόρος εξέλιξη αυτού του συνόλου μπορεί να συμβεί με διαφορετικούς τρόπους οι οποίοι αριθμητικά είναι πολλοί, στην πραγματικότητα όμως αντλούνται από ένα συγκεκριμένο σύνολο εναλλακτικών, οι οποίες ορίζονται από περιορισμούς που αφορούν στους νόμους της φύσης, την ανθρώπινη φύση και στόχους, το ρόλο του χρόνου και της εξέλιξης της πραγματικότητας.

Στο εν λόγω πλαίσιο η αειφορία γίνεται αντιληπτή όχι ως σταθερός, αντικειμενικός στόχος, αλλά ως μια συνεχώς εξελισσόμενη διαδικασία δυναμικών σχέσεων μεταξύ πλήθους παραγόντων, χαρακτηριζόμενη από αβεβαιότητα και συνεχώς μεταβαλλόμενο περιβάλλον. Η μετάφραση της έννοιας ως αναζήτηση σταθερότητας και ισορροπίας, όπως ήταν αντιληπτή έως τώρα, χάνει τη σημασία της, αφενός γιατί σύμφωνα με αυτή την προσέγγιση τίποτα δεν είναι δυνατό να παραμείνει στάσιμο στην πραγματικότητα (IISD, 1999), αφετέρου γιατί στο σκεπτικό της πολυπλοκότητας «η αστάθεια είναι απαραίτητη προϋπόθεση της ανάπτυξης» (De Roo et al., 2010). Η αναζήτηση της ισορροπίας λοιπόν θεωρείται επιζήμια για την ανάπτυξη του συστήματος, το οποίο καλείται να λειτουργήσει σε συνθήκες αυξημένης πολυπλοκότητας, ώστε να είναι δημιουργικό και να επανεφευρίσκει τον εαυτό του (Baggio, 2008), κάτι που τελικά οδηγεί στην ουσία της αειφορίας, ως διατήρηση και βιώσιμη εξέλιξη στον χρόνο.

Η αειφορία σήμερα συνοδεύεται από μια νέα γενιά μεθόδων και εργαλείων που πρακτικά συμπληρώνουν ή αντικαθιστούν τους παραδοσιακούς της δείκτες: σχεδιασμό σεναρίων (scenario planning), ολοκληρωμένα μοντέλα επιπτώσεων (integrated assessment models), μοντέλα προσομοίωσης (simulation models), συστήματα γεωγραφικών πληροφοριών (geographical information systems), προσαρμοστική διαχείριση (adaptive management) και πιο πρόσφατα ανάλυση και διαχείριση ανθεκτικότητας (resilience analysis and management). Η τελευταία αποτελεί μια σύγχρονη έννοια-πλαίσιο, η οποία χρησιμοποιείται πέρα από την οικολογία, τη φυσική και τη μηχανική, στην ψυχολογία, στη διαχείριση κινδύνων και φυσικών καταστροφών, στη διακυβέρνηση και στον περιβαλλοντικό και αστικό σχεδιασμό (Davoudi, 2012). Στη βιβλιογραφία έχουν πραγματοποιηθεί πολλές συνδέσεις μεταξύ ανθεκτικότητας και αειφορίας. Επιχειρώντας να αποσαφηνίσει τη διαφορά ανάμεσα στην ανθεκτικότητα και την αειφορία, ο Adger (2010) αντιδιαστέλλει την κανονιστική και την περιγραφική φύση των δύο όρων. Η αειφορία, ειδικά από τον πολιτικό κόσμο, γίνεται αντιληπτή ως ένας σκοπός, ένα ιδανικό προς το οποίο πρέπει να τείνει η διαχείριση του κοινωνικού, οικονομικού και περιβαλλοντικού συστήματος (Derissen et al., 2011).

Η ανθεκτικότητα από την άλλη, σχετίζεται περισσότερο με την προσέγγιση της αειφορίας και γίνεται αντιληπτή ως μια ιδιότητα του συστήματος που βρίσκεται συνεχώς σε εξέλιξη. Οι Derissen et al. (2011) εντοπίζουν ως κύρια διαφορά μεταξύ των δύο εννοιών στο γεγονός ότι η αειφόρος ανάπτυξη επιδιώκει να αποφύγει το όποιο σοκ συμπεριφερόμενη με προσοχή στο περιβάλλον και την κοινωνία, ενώ ο σχεδιασμός της ανθεκτικότητας προσαρμόζεται στην εκάστοτε μεταβολή με στόχο να επιστρέψει σε μια επιθυμητή κατάσταση, διαφυλάσσοντας παράλληλα την εμπειρία αυτής προσαρμογής, ώστε το σύστημα να ανταπεξέλθει με μεγαλύτερη αποτελεσματικότητα σε μελλοντικές προκλήσεις. Υπό αυτές τις συνθήκες, η τελευταία είναι πιο άμεσα και πρακτικά σχετιζόμενη με την πραγματικότητα, καθώς προσφέρει μεγαλύτερο εύρος πιθανών μελλοντικών καταστάσεων απ' ότι η αειφορία, η οποία στοχεύει σε μια ιδανική κατάσταση συντήρησης και επιθυμητής σταθερότητας (Lew, 2013).

4. Από τον μετριασμό στην προσαρμογή: η πρόκληση για τον σχεδιασμό

Οι δύο κύριες κατηγορίες απάντησης στο πρόβλημα της κλιματικής αλλαγής, αφορούν στο μετριασμό (mitigation) και στην προσαρμογή (adaptation). Ο μετριασμός έχει ως στόχο τον περιορισμό των μελλοντικών επιπτώσεων της κλιματικής αλλαγής μέσω κυρίως της μείωσης των αερίων που συμβάλλουν στο φαινόμενο του θερμοκηπίου (Füssel, 2007). Η προσαρμογή αναζητά τον τρόπο με τον οποίο ο άνθρωπος μπορεί να ζήσει σε αρμονία με τις συνέπειες των μεταβολών του κλίματος, στο βαθμό που αυτό βέβαια είναι εφικτό. Είναι μια διαδικασία ή σύνολο μέτρων, που στοχεύει στη μείωση της ευπάθειας των φυσικών και ανθρωπογενών συστημάτων έναντι τρεχόντων ή αναμενόμενων επιπτώσεων της κλιματικής αλλαγής (EC, 2013). Τόσο ο επιστημονικός, όσο και ο πολιτικός κόσμος έδωσαν έως τώρα μεγαλύτερη έμφαση στην ανάπτυξη τεχνικών μετριασμού, παρά στην προσαρμογή στην κλιματική αλλαγή (Füssel, 2007; Roggema, 2012). Πρόκειται για μια πρακτική που δικαιολογείται αφενός από το γεγονός ότι η πρόληψη θεωρείται πάντα η καταλληλότερη προσέγγιση ενός προβλήματος, στοχεύοντας στην αιτία της ύπαρξής του, αφετέρου από το ότι τα αποτελέσματα των προσπαθειών της μείωσης των κακόβουλων αερίων είναι πιο απτά και εύκολα αξιολογήσιμα σε σχέση με μια πολιτική προσαρμογής (Füssel, 2007).

Παρόλα αυτά, σήμερα παρατηρείται ολοένα αυξανόμενο ενδιαφέρον σχετικά με την αναγκαιότητα της προσαρμογής στην κλιματική αλλαγή. Έχει γίνει κατανοητό πως η ολική αποτροπή του προβλήματος δεν είναι εφικτή και πως ακόμα και αν οι μεταβολές του κλίματος μετριαστούν, είναι τόσο αδύνατο, όσο και αφύσικο να εκλείψουν (Roggema, 2012). Η Ευρωπαϊκή Ένωση, με την έκδοση της Λευκής Βίβλου «Η προσαρμογή στην αλλαγή του κλίματος: προς ένα ευρωπαϊκό πλαίσιο δράσης» τον Απρίλιο του 2009, υπογράμμισε την ανάγκη χάραξης ολοκληρωμένης στρατηγικής με στόχο την άμβλυνση των επιπτώσεων της κλιματικής αλλαγής και κάλεσε τα κράτη μέλη να εκπονήσουν αντίστοιχα Εθνικά Σχέδια Προσαρμογής (Ε.Κε.Π.Ε.Κ. et al., 2011). Μέσα σε αυτό το πλαίσιο και λόγω της φύσης του προβλήματος, ο σχεδιασμός του χώρου και η περιβαλλοντική διαχείριση, προκειμένου να ανταποκριθούν στις νέες απαιτήσεις, καλούνται να διαδραματίσουν έναν συνδυαστικό ρόλο, αναθεωρώντας παράλληλα στόχους, μεθόδους και διαδικασίες (Davoudi, 2009; Roggema, 2012).

Η μεγαλύτερη ίσως πρόκληση ως προς την ουσία του σχεδιασμού είναι η αποδοχή της πολυπλοκότητας του διαχειριζόμενου προβλήματος και η συμφιλίωση με την ύπαρξη αβεβαιοτήτων και πολλαπλών πιθανών μελλόντων, λιγότερο ή περισσότερο αισιόδοξων. Πολλοί μελετητές αναφέρονται στην ανάγκη μιας ριζικής στροφής στον τρόπο σκέψης και αντιμετώπισης των πολύπλοκων προβλημάτων (Sanders et al., 2003), σημειώνοντας πως οι έως τώρα αποτυχίες δεν οφείλονται τόσο στην πολύπλοκη φύση των διαχειριζόμενων διαδικασιών, όσο στο γεγονός ότι οι μεθοδολογίες που χρησιμοποιήθηκαν δομήθηκαν πάνω σε μια απλουστευμένη αντίληψη της πραγματικότητας (De Roo et al., 2010). Επιμένουν πως ο στόχος δεν θα πρέπει να είναι να μειωθεί η αβεβαιότητα και να υποστεί διαχείριση η πολυπλοκότητα, αλλά αυτές να κατανοηθούν και να χρησιμοποιηθούν για την ανάπτυξη νέων μεθοδολογιών σχεδιασμού του χώρου, που θα συν-προσαρμόζονται και θα συν-εξελίσσονται με τις δυναμικές χωρικές διαδικασίες (Allen, 2012). Σύμμαχος σε μια τέτοια πρακτική είναι οι νέες τεχνολογίες και τα εξελιγμένα υπολογιστικά μοντέλα προσομοίωσης, που παρέχουν εργαλεία με αυξημένες δυνατότητες, παρέχοντας τα μέσα αποφυγής παλαιότερων αναγκαστικών απλουστεύσεων (Allen, 2012; Portugali et al., 2012).

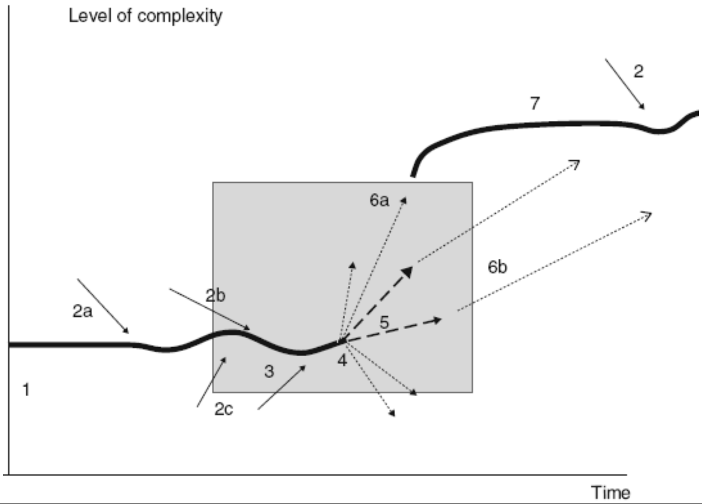
Υπό αυτές τις συνθήκες, η προσαρμογή στο πρόβλημα της κλιματικής αλλαγής απαιτεί να τεθεί σε εφαρμογή η πλέον σύγχρονη μέθοδος σχεδιασμού, γνωστή ως «προσαρμοστική διαχείριση» (adaptive management) (Roggema, 2012). Όπως φαίνεται στην Εικόνα 1, η προσαρμοστική διαχείριση μπορεί να περιγραφεί στο πλαίσιο των πολύπλοκων συστημάτων. Καθώς η πολυπλοκότητα και η αβεβαιότητα αυξάνουν, ο σχεδιασμός καλείται να αποσταθεροποιηθεί και να αναδιοργανωθεί. Μόνο σε μια τέτοια περίπτωση θα είναι ικανός να ανταποκριθεί σε αβέβαιες συνθήκες. Με άλλα λόγια ο σχεδιασμός καλείται να λάβει μέρος σε μια διαδικασία διαδοχικής κατανόησης και επεξεργασίας μιας σειράς από πολύπλοκα παρόντα και αβέβαιες προβλέψεις, προκειμένου να προσεγγίσει το μέλλον, στο οποίο στοχεύει. Το ερώτημα είναι πώς αυτή η διαδικασία θα εισχωρήσει και θα χαρακτηρίσει το σύνολο του σχεδιασμού και τη διαδικασία λήψης αποφάσεων. Προς αυτή την κατεύθυνση, η προσαρμογή στην κλιματική αλλαγή καλείται να αποτελέσει αναπόσπαστο μέρος της διαδικασίας του σχεδιασμού, με παρόμοιο τρόπο με τον οποίο εκτίμηση περιβαλλοντικών επιπτώσεων έχει ενσωματωθεί σήμερα σε σχεδόν όλα τα στρατηγικά προγράμματα και σχέδια (Lazarevic-Bajec, 2011).

5. Ο ρόλος της Στρατηγικής Εκτίμησης Περιβαλλοντικών Επιπτώσεων

Η Στρατηγική Μελέτη Περιβαλλοντικών Επιπτώσεων, η οποία στο πλαίσιο της Ευρωπαϊκής Ένωσης διέπεται από την οδηγία «για την εκτίμηση των επιπτώσεων ορισμένων σχεδίων και προγραμμάτων για το περιβάλλον» (2001/42/ΕΚ), θεωρείται ιδιαίτερα κατάλληλο θεσμικό και μεθοδολογικό πλαίσιο, ως προς την ενσωμάτωση των στόχων της προσαρμογής στην κλιματική αλλαγή, λόγω της προσπάθειάς της να προσεγγίσει το μέλλον, της ελευθερίας που παρέχει ως προς την κλίμακα μελέτης (σε αντίθεση με τις Μελέτες Περιβαλλοντικών Επιπτώσεων, οι οποίες είναι ιδιαίτερα περιορισμένες), του μακροχρόνιου χαρακτήρα της και της μελέτης συσσωρευτικών και συνδυαστικών παραγόντων που δρουν στο ανθρωπογενές και φυσικό περιβάλλον (Posas, 2011; Wende et al., 2012). Γίνεται κατανοητό πως όλα αυτά είναι στοιχεία που έχουν άμεση σχέση με τη φύση του προβλήματος της κλιματικής αλλαγής, όπως αυτό περιγράφηκε προηγουμένως.

Η οδηγία επισημαίνει την ανάγκη να λαμβάνονται υπόψη «κλιματικοί παράγοντες» κατά τη διεξαγωγή της εκάστοτε μελέτης. Οι πρόσφατες όμως εξελίξεις στον τομέα της επιτακτικής προσαρμογής στην κλιματική αλλαγή, αποτέλεσαν την αφετηρία για μια συζήτηση ως προς το κατά πόσο, τόσο ο μετριασμός, όσο και η προσαρμογή στην κλιματική αλλαγή θα πρέπει να αντικατοπτρίζονται εντονότερα στη μεθοδολογία και τα αποτελέσματα των ΣΜΠΕ (Posas, 2011). Ακολούθως, η ΕΕ, μεταξύ ενός συνόλου διαφορετικών συγγραφέων και οργανισμών, ανέπτυξε ειδικές κατευθυντήριες γραμμές για την ενσωμάτωση της κλιματικής αλλαγής σε ΣΜΠΕ, στην οποία διερευνώνται παράλληλα οι δεσμοί μεταξύ της αλλαγής του κλίματος και της βιοποικιλότητας (EC, 2013; Posas, 2011).

Το τελευταίο αυτό κείμενο της ΕΕ, «Guidance on Integrating Climate Change and Biodiversity into Strategic Environmental Impact Assessment» (EC, 2013), έχει ιδιαίτερο ενδιαφέρον. Καλεί τις ΣΜΠΕ προς εκ των βάσεων αναδιαμόρφωση, προκειμένου να ανταπεξέλθουν στους πιθανούς, μακροπρόθεσμους κινδύνους που θέτει το πολύπλοκο, όπως αναφέρεται χαρακτηριστικά, πρόβλημα της κλιματικής αλλαγής. Το νέο πλαίσιο στο οποίο καλούνται οι ΣΜΠΕ να λειτουργήσουν είναι αυτό της ανθεκτικότητας και η προτεινόμενη μεθοδολογία αφορά στην προσαρμοστική διαχείριση. Στο πλαίσιο των ΣΜΠΕ, αυτό σημαίνει ότι πρέπει να γίνει κατανοητό πως το υπό μελέτη πρόγραμμα/σχέδιο καλείται να λειτουργήσει μέσα σε μια δυναμική, συνεχώς εξελισσόμενη περιβαλλοντική κατάσταση. Ως εκ τούτου, η ΣΜΠΕ πρέπει να κατανοεί τις διαρκώς μεταβαλλόμενες πιέσεις της περιβαλλοντικής αυτής κατάστασης στο σχέδιο και να μεταλλάσσεται κατάλληλα, ώστε να ανταποκρίνεται στα εκάστοτε δεδομένα. Για να προσεγγισθεί το παραπάνω σκεπτικό πρακτικά, παρέχονται στο ίδιο κείμενο μια σειρά από γενικές κατευθύνσεις, κατηγοριοποιημένες ανάλογα, ώστε να ανταποκρίνονται στις προκλήσεις που θέτει το πολυσύνθετο πρόβλημα της κλιματικής αλλαγής (Πίνακας 1).



1. Η τρέχουσα , δυναμική κατάσταση πολύπλοκου συστήματος 2a, 2b, 2c: Αλλαγές στο περιβάλλον του συστήματος με αποτέλεσμα πιέσεις για αλλαγή της κατάστασής του. 3. Προσπάθειες εντός του συστήματος να προσαρμοστεί στις εξωτερικές αλλαγές παραμένοντας στην τρέχουσα κατάσταση και αποφεύγοντας μια κρίση. 4. Χαοτική φάση της αύξησης της πίεσης στο σύστημα, το οποίο δεν είναι πλέον λειτουργικό στην τρέχουσα κατάσταση. 5. Αιφνίδια γεγονότα του εσωτερικού ή εξωτερικού περιβάλλοντος, επιτάχυνση της αλλαγής (5). 6. Ξαφνικές και ταχείες αλλαγές, το σύστημα εξελίσσεται σε κυρίαρχη κατεύθυνση προς μια προτιμώμενη, αλλά δύσκολα προβλέψιμη κατάσταση. 7 (το νέο 1). Η νέα ρουτίνα του πολύπλοκου συστήματος. Στο γκρι πλαίσιο η θέση όπου καλείται να λάβει μέρος ο σχεδιασμός (προσαρμοστική διαχείριση) ώστε να ανταπεξέλθει στις κρίσεις που υφίσταται το σύστημα.

Εικόνα 1: Η προσαρμοστική διαχείριση στο πλαίσιο της συμπεριφοράς των πολύπλοκων συστημάτων
Πηγή: Roggema, 2012. Ιδία επεξεργασία.

6. Προς μια Στρατηγική Προσαρμογής για την Ελλάδα

Η Ελλάδα, παρόλο που χαρακτηρίζεται ιδιαίτερα ευάλωτη λόγω της γεωγραφικής της θέσης και της εκτεταμένης ακτογραμμής της όσο αφορά στην κλιματική αλλαγή, δεν έχει εκπονήσει μέχρι στιγμής εθνική στρατηγική για τη προσαρμογή, ούτε έχει προχωρήσει σε μια αξιολόγηση των κινδύνων που συνδέονται άμεσα ή και έμμεσα με τις επιπτώσεις της (MinEnv, 2014). Η Τράπεζα της Ελλάδος, με έκθεσή της το 2011, για τις επιπτώσεις της κλιματικής αλλαγής στην Ελλάδα, κλήθηκε να καλύψει ένα κενό. Παρόλα αυτά, η πρόκληση μιας ενιαίας στρατηγικής παραμένει. Σύμφωνα με μελέτη του ΟΟΣΑ, η Ελλάδα ανήκει στην ομάδα των χωρών που αν και έχουν αναγνωρίσει την ανάγκη και τις ευκαιρίες για προσαρμογή στην κλιματική αλλαγή, αντιμετωπίζουν προς το παρόν τις προκλήσεις συζητώντας σε ένα γενικό επίπεδο και χωρίς να αναφέρονται σε συγκεκριμένες δράσεις (OECD, 2006). Σύμφωνα με την 6η Ανακοίνωση της Ελλάδας προς την Γραμματεία της Σύμβασης Πλαίσιο για την Κλιματική Αλλαγή στη Βόννη, η έμφαση εξακολουθεί να δίνεται στο θέμα του μετριασμού των εκπομπών και λιγότερο στην προσαρμογή (MinEnv, 2014). Αναφέρεται πως τα μέτρα προσαρμογής που βρίσκονται σε εξέλιξη αποτελούν μέρος ενός ευρύτερου δικτύου των μέτρων που ισχύουν για συγκεκριμένες περιοχές, όπου εντοπίζονται τα τρωτά σημεία (π.χ. για την ερημοποίηση, την αγροτική παραγωγή, τα δάση, τις παράκτιες περιοχές, τον τουρισμό κλπ). Αυτή όμως η σπασμωδική αντιμετώπιση σε καμιά περίπτωση δεν μπορεί να λειτουργήσει ως υποκατάστατο μιας καλά σχεδιασμένης στρατηγικής, σε εθνικό και τοπικό επίπεδο.

Πίνακας 2: Συμβουλές για την ενσωμάτωση της κλιματικής αλλαγής (και της βιοποικιλότητας) στις ΣΜΠΕ

Κύριες προκλήσεις για την ενσωμάτωση της κλιματικής αλλαγής (και της βιοποικιλότητας) στη ΣΜΠΕ	Συμβουλές για την αντιμετώπιση των προκλήσεων
Μακροχρόνιος και σωρευτικός χαρακτήρας των επιπτώσεων	Αποφυγή στατικών και στιγμιαίων αναλύσεων και μελέτη των τάσεων με ή χωρίς το προτεινόμενο πρόγραμμα.
Πολυπλοκότητα και σχέσεις αιτίας-αιτιατού	Ανάλυση επιπτώσεων του προτεινόμενου προγράμματος στις κύριες τάσεις της κλιματικής αλλαγής και στα στοιχεία που τις επηρεάζουν. Ταυτόχρονη μελέτη του καλύτερου και χειρότερου μελλοντικού σεναρίου.
Αβεβαιότητα	Αναγνώριση των απλουστευμένων παραδοχών και των ορίων της δυνατής γνώσης. Η αρχή της πρόληψης ως βάση των προτεινόμενων δράσεων. Ετοιμότητα για προσαρμοστική διαχείριση.

Πηγή: **EC (2013)**

Μια άλλη συμβολή, η έκθεση «Οδικός Χάρτης για την προσαρμογή της Ελλάδας στην κλιματική αλλαγή» (Ε.Κε.Π.Ε.Κ. κ.α.., 2011) προτείνει θεσμικές αλλαγές και μέτρα ώστε η χώρα να αποκτήσει δεσμευτικό Εθνικό Σχέδιο Δράσης, που θα βοηθήσει προς την προσαρμογή. Σημειώνοντας το ρόλο του χωροταξικού σχεδιασμού στην όλη διαδικασία, η έκθεση χαρακτηριστικά αναφέρει: *«κατά τη διαδικασία εκπόνησης του χωροταξικού σχεδιασμού είναι απαραίτητο να αξιολογούνται οι μελλοντικοί κλιματικοί κίνδυνοι (π.χ. στις παράκτιες ζώνες, ή σε περιοχές ευπαθείς σε πλημμύρες) και να διασυνδεθεί συστηματικά η έννοια της βιώσιμης χωρικής ανάπτυξης με τις αναμενόμενες φυσικές μεταβολές στον Ελλαδικό χώρο (π.χ. εντονότερη ξηρασία σε ορισμένες περιοχές, τρωτότητα άλλων περιοχών σε φυσικές καταστροφές)»*. Σε αυτό το σημείο είναι που μπορεί να εντοπιστεί ο ρόλος της ΣΜΠΕ, ως ένα εργαλείο άμεσα μελλοντικού προσανατολισμού, ικανό να συνδυάσει τους στόχους και τις στρατηγικές του χωροταξικού σχεδιασμού της χώρας, με την ανάγκη εκάστοτε προσαρμογής τους στις κλιματικές αλλαγές.

Γίνεται κατανοητό, πως ακόμα και στην περίπτωση εκπόνησης μιας Εθνικής Στρατηγικής, η τομεακή προσέγγιση και ο κατακερματισμός των στόχων είναι δύσκολο να αποφευχθεί. Άλλωστε πάντα αποτελεί πρόκληση η μεταφορά των επιστημονικών απαιτήσεων στην πράξη. Η ΣΜΠΕ όμως, με κατάλληλη αναδιαμόρφωσή της στα πλαίσια της ανθεκτικότητας και της προσαρμοστικής διαχείρισης, μπορεί να αποτελέσει κινητήρια δύναμη βελτίωσης του υπάρχοντος συστήματος προγραμματισμού και συντονισμού μεταξύ των υπεύθυνων αρχών σύνταξης τομεακών προγραμμάτων (Βλαντού, 2009) και να κατευθύνει σταδιακά τον σχεδιασμό προς την απόκτηση μιας νέας κοινής γλώσσας, άμεσα σχετιζόμενης με τις σύγχρονες επιστημονικές αναζητήσεις. Προς αυτή την κατεύθυνση σύμμαχο αποτελούν οι καλές πρακτικές τους εξωτερικού. Χαρακτηριστικά αναφέρεται πως στην Ολλανδία, μια χώρα με μεγάλη εμπειρία σε θέματα περιβαλλοντικής διαχείρισης, ο θεσμός των ΣΜΠΕ αξιοποιείται και επεκτείνεται με τη δημιουργία κατάλληλων τομεακών μελετών επιπτώσεων, που διατρέχουν τον σχεδιασμό και τις προσπάθειες προσαρμογής στην κλιματική αλλαγή (Swart et al., 2009). Επιπλέον, το Ολλανδικό National Environmental Assessment Agency είναι μια ανεξάρτητη συμβουλευτική οργάνωση που εκπονεί τέτοιες μελέτες αποτελώντας τον απαραίτητο συνδετικό κρίκο μεταξύ της επιστημονικής έρευνας και της άσκησης πολιτικών, απαντώντας σε μια άλλη πρόκληση που σε μεγάλο βαθμό αντιμετωπίζει η Ελλάδα, αυτή των επιστημονικά τεκμηριωμένων και ευσυνείδητα εκπονημένων ΣΜΠΕ.

7. Συμπεράσματα

Με βάση τη θεώρηση των πολύπλοκων συστημάτων καταδεικνύεται ότι η αειφόρος ανάπτυξη, δεν θα έπρεπε να εκλαμβάνεται ως ουτοπικός στόχος, αφού μπορεί να υπάρξει και μέσα από την κλιματική αλλαγή με μία νέα, μη ντετερμινιστικά προσδιοριζόμενη, μορφή. Συνεπώς, οι δράσεις ανάσχεσης του φαινομένου της κλιματικής αλλαγής, ως προς την ανθρωπογενή συνιστώσα της, θα πρέπει να εμπλουτισθούν με αντίστοιχες προσαρμογής σε αυτή. Για το σκοπό αυτό απαιτείται αφενός η αξιοποίηση των σύγχρονων επιστημονικών γνώσεων, οι οποίες υπαγορεύουν μια στροφή στον τρόπο με τον οποίο γίνεται αντιληπτός ο σχεδιασμός, αφετέρου η εύρεση αυτού του μεθοδολογικού και θεσμικού εργαλείου που θα μεταφράσει τη γνώση σε πολιτική.

Συνεπώς, για την Ελλάδα, αλλά και άλλες χώρες, η πρόκληση δεν περιορίζεται στη διαμόρφωση Εθνικής Στρατηγικής για την προσαρμογή στην κλιματική αλλαγή, αλλά επεκτείνεται στην εύρεση εκείνων των εργαλείων που θα ανταποκριθούν στις απαιτήσεις της πολυπλοκότητας του προβλήματος και θα λειτουργήσουν στη βάση της προσαρμοστικής διαχείρισης. Οι ΣΜΠΕ, αναγνωρίζονται λόγω της φύσης τους ως εργαλεία ικανά να διαδραματίσουν αυτό τον ρόλο. Αν αξιοποιηθούν κατάλληλα, η Ελληνική Στρατηγική Προσαρμογής είναι ικανή να τεθεί σε εφαρμογή άμεσα, αναδιαμορφώνοντας υπάρχουσες διαδικασίες και χωρίς την απαίτηση να αναζητηθούν λύσεις εκ νέου. Ενδιαφέρον έχει σε επόμενο επίπεδο να εξεταστεί η ακριβής μεθοδολογία των αναδιαμορφωμένων ΣΜΠΕ, καθώς και να διαμορφωθεί η ακριβής θεσμική σχέση ΣΜΠΕ-Στρατηγικής Προσαρμογής.

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Corporate Social Responsibility: Firms environmental practices and consumer perceptions

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Abstract

The deployment of environmental friendly business practices is strongly related to the principles of the sustainable development. An important stakeholder group that appears to be prone to a company's CSR actions is its customers. The aim of this study is to examine the determinants that affect consumer perceptions towards CSR and especially environmental friendly strategies, employing data from Athens, Greece. Results suggest that consumers' knowledge of CSR environmental actions of a firm positively affects their purchasing habits. Consumer supports the environmentally responsible businesses. Highly educated consumers are more prone to CSR environmental actions. However, the results suggest that income of the consumer is not statistically significant factor for consumers' awareness and the preference towards socially responsible firms that encompass environmental friendly actions. Finally, it is estimated that consumers who prefer to buy products based on the environmental practices of the firm are women and highly educated persons.

Keywords: Firms, CSR, Consumer Behaviour.

Εταιρική Κοινωνική Ευθύνη: Οι αντιλήψεις των καταναλωτών για τις περιβαλλοντικές πρακτικές των επιχειρήσεων

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Περίληψη

Η ανάπτυξη φιλικών προς το περιβάλλον επιχειρηματικών δράσεων είναι στενά συνδεδεμένη με τις αρχές της βιώσιμης ανάπτυξης. Οι καταναλωτές αποτελούν μια σημαντική ομάδα ενδιαφερομένων που επηρεάζονται από τις δράσεις Εταιρικής Κοινωνικής Ευθύνης των επιχειρήσεων. Ο σκοπός της παρούσας μελέτης είναι να εξετάσει τους παράγοντες που επηρεάζουν τις αντιλήψεις των καταναλωτών σχετικά με τις δράσεις ΕΚΕ και ιδιαίτερα τις περιβαλλοντικά φιλικές στρατηγικές. Η εμπειρική ανάλυση βασίζεται σε διαστρωματικά δεδομένα όπως προέκυψαν από έρευνα σε δείγμα καταναλωτών στην περιοχή της Αθήνας. Τα εμπειρικά αποτελέσματα υποδηλώνουν ότι οι περιβαλλοντικές στρατηγικές των επιχειρήσεων που αναπτύσσονται στο πλαίσιο της ΕΚΕ τους έχει θετικό αντίκτυπο στην πρόθεση αγοράς των καταναλωτών για τα προϊόντα τους. Τα αποτελέσματα υποδηλώνουν ότι το εισόδημα του καταναλωτή δεν αποτελεί στατιστικά σημαντικό παράγοντα για την ενημέρωσή τους και την προτίμηση τους για προϊόντα που παράγονται από κοινωνικά υπεύθυνες εταιρίες. Τέλος, εκτιμάται

ότι οι καταναλωτές που προτιμούν να αγοράζουν προϊόντα με κριτήριο την ανάπτυξη περιβαλλοντικά φιλικών πρακτικών στο πλαίσιο της ΕΚΕ των επιχειρήσεων είναι γυναίκες και άτομα με υψηλό μορφωτικό επίπεδο.

Λέξεις κλειδιά: Επιχειρήσεις, ΕΚΕ, Συμπεριφορά Καταναλωτή.

1. Introduction

The deployment of environmental friendly business practices is strongly related to the principles of the sustainable development. An important stakeholder group that appears to be prone to a company's CSR actions is its customers. There is a body of research attempting to define what it means for a company to be socially responsible. The most widespread definition of corporate social responsibility is that of Carroll's pyramid (1991). Carroll (1991) stated that social responsibility of business encompasses four dimensions in the following decreasing order of importance, namely: economic, legal, ethical and philanthropic responsibilities. An extension of Carroll's concept that captures the environmental dimension of a company's social responsibility is that developed by European Commission (2001). Similarly, Mohr et al. (2001) and Rathin et al. (2011) mentioned that corporate socially responsible behaviours include a broad array of actions aimed at minimizing damage to the environment. Consumers' perception of a company's environmental performance is supposed to positively influence intended purchase behaviour (Grimmer and Bingham, (2013). Companies, however, focus on the core stakeholders (Öberseder et al., 2013) and consumers are not aware of environmental activities adopted by them (Singh et al., 2008).

The bulk of the research attests that there is a positive influence of CSR actions on financial performance of the companies. In this context, most of the studies focused on the fact that companies that publicize their socially responsible actions can positively impact consumers' purchase behaviour (Sen and Bhattacharya, 2001; Wigley S., 2008; Marquina P. and Morales, 2008; Groza et al., 2011, Rathin et al., 2011 and Tian et al., 2011). However, the influence of CSR on consumers' decision process is complex and differentiates between intention and actual behaviour. More specifically, Tian et al. (2011) found the awareness of socially responsible actions had a significant positive effect only on consumers' purchase intention. Mohr et al. (2001) also confirmed that only a limited segment of consumers thought as a purchasing criterion whether the product was made from socially responsible companies. Similarly, Gupta and Hodges (2012) concluded that price and quality of the product was much more important purchasing criterion rather than whether the product was made under CSR conditions. Finally, Papadopoulos et al. (2011) indicated that Greek consumers should be convinced about the sincerity of the CSR policies to behave positively. However, CSR practises may affect indirectly the company's financial performance (Wigley, 2008). Consumers' studies suggested that CSR activities generated a competitive advantage to the company, through brand loyalty and differentiation (Luo and Bhattacharya, 2006; Marquina and Morales, 2008 and Stanaland et al., 2011), influenced corporate reputation and trust, through advertising (Bhattacharya and Malani, 2013; Öberseder et al, 2013) and consequently benefited product sales (Bhattacharya and Malani, 2013).

Consumers believed that rewarding companies that adopt CSR activities could be a motivating factor for other companies to be more socially responsible (Gupta and Hodges, 2012), were more willing to purchase products from companies that care about society (Sen and Bhattacharya, 2001; Grimmer and Bingham, 2013) and pay more for them (Gupta and Hodges, 2012). However, Bhattacharya and Malani (2013) concluded that the minority of the respondents were prone to pay higher prices for products of socially responsible companies. In the same context, Gupta and Hodges (2012) pointed out that although consumers were willing to pay more, they disagreed about the amount of charge and though that it was not right for them to pay for CSR activities. Contrary, it is estimated that if the price and the quality of two products were the same, consumers would buy from the company that act in an ethical and socially responsible manner (Maignan, 2001; Singh et al., 2008).

Several empirical studies had been conducted to measure consumers' awareness toward a company's CSR actions (Maignan, 2001; Mohr et al., 2001; Singh et al., 2008; Lee and Shin, 2010; Rathin et al., 2011 and Gupta and Hodges, 2012). All these studies highlighted the need for more communication of CSR practices. In particular, consumers declared that they had a difficulty to understand the concept of CSR (Singh et al., 2008 and Rathin et al., 2011) and lack of awareness or low level of awareness is confirmed to be major barrier to positive attitudes and purchase decisions toward a socially responsible company (Maignan, 2001; Lee and Shin, 2010 and Gupta and Hodges, 2012). Lack of awareness is attributed mainly to difficulties obtaining information on the social responsibility actions of a firm (Mohr et al., 2001) which could lead to a higher level of purchase intention (Maignan, 2001). As Bhattacharya and Sen (2004) confirmed, consumers evaluated better a company when provided with information about its CSR record.

Limited studies have been conducted on the demographic characteristics of consumers who respond positively to CSR activities. Results indicated that that women, higher-education, and higher-income groups are more supportive of company's socially responsible actions (Youn and Kim, 2008). Carrigan et al. (2004) found that older consumers are more likely to purchase products taking into account ethical issues, whereas Tian et al. (2011) concluded that consumers with a middle level of income and age would be more supportive of a firm's CSR practices.The current research examines CSR from the consumers' perspective, focusing on environmental dimensions of a socially responsible company. The aim of this study is twofold: (i) to examine the demographic determinants that affect consumers' awareness of company's environmental responsible action and (ii) to estimate the socioeconomic profile of the consumers who prefer to buy products/services from companies that encompasses environmental activities in their CSR plan. For the purpose of the study, we carried out an extensive survey of 500 consumers in Athens in 2013. The survey was based on a questionnaire, which was administered using face-to-face interviews with each consumer. We chose consumers because we expect that by understanding consumer attitudes to CSR environmental dimensions, companies can not only develop appropriately their marketing campaigns but also adopt sustainability patterns.

The structure of the paper is the following. The next section presents the data and the adopted methodology of the analysis. Then the empirical results derived are presented and discussed. The last section concludes the paper and present policy implications of the analysis.

2. Data and Methodology

The research presents some insights into the determinants that affect consumers' attitudes towards CSR, focusing on environmental friendly actions. Data for the current research were obtained from a random sample of 500 consumers. The survey took place from April to June 2013, in the area of Athens, using an anonymous structured questionnaire. The questionnaire consisted of two sections: The first section included closed type questions on demographic and economic characteristics of the consumers such as gender, age, educational background and monthly private income. In the second section, consumers were asked to describe their attitudes towards firms that adopt CSR actions aimed at environmental protection.

Empirical results are based on the estimation of logistic regression models. Logistic regression is used for predicting the probability of an event occurring by fitting data to a logit function. In our case, under the binary logistic model, the estimated value of the dependent variable is interpreted as the probability that a consumer is aware of a socially responsible company targeting environmental protection, as identified by the values of the explanatory independent variables. Therefore, in the empirical study, we employed the following expanded specification for a consumer's awareness of a company's socially responsible activities targeting environmental protection:

$$\begin{aligned} Logit[\Pr(Y=1)] = \beta_o + \beta_1 gender + \beta_2 age + \beta_3 age2 + \beta_4 education + \beta_5 income + \beta_6 envir \\ + \beta_7 icsr + \varepsilon_{it} \qquad (1) \end{aligned}$$

where Y is a binary variable indicating whether the consumer is aware of a company that adopts corporate environmental responsible activities or not; specifically, the variable takes the value 1 when the consumer is aware of corporate environmental responsible activities and zero otherwise. $gender_i$ is a dummy variable accounting for 1 if the respondent is female and zero if male; age is the consumer's age; age2 is the square of the consumer's age; education is a dummy variable accounting for 1 if the respondent has completed graduate studies and zero otherwise; income is the consumer's monthly private income in euros; envr is a dummy variable accounting for 1 if the respondent participates in environmental friendly actions; icsr is a dummy variable accounting for 1 if the consumer has previously sought information on CSR dimensions and ε_{it} is disturbance term. The empirical results from the estimation of Eq. (1) are presented in Table 1 in the next section of this study.

Next, an ordered logistic regression model is estimated to predict the level of agreement regarding the statement "I prefer to buy products/services from companies that encompasses environmental activities in their CSR plan" (Answers: Disagree, Neutral, Agree). The general specification of the proposed model is:

$$\begin{aligned} y_i^* = \gamma_o + \gamma_1 gender + \gamma_2 age + \gamma_3 income + \gamma_4 exmoney + \gamma_5 education + \gamma_6 envir \\ + \gamma_7 advertisme\,nt + \gamma_7 price + \gamma_8 quality + \gamma_8 icsr + \varepsilon_{it} \qquad (2) \end{aligned}$$

where y_i^* is the latent variable measuring the level of consumer's preference toward companies that encompasses environmental activities in their CSR plan; exmoney is a dummy variable accounting for 1 if the respondent is willing to pay more for products from a socially responsible company given that price and quality is equal and zero otherwise; advertisement, price and quality are qualitative variables that express the importance of choosing products under the specific criteria. The empirical results from the estimation of Eq. (2) are presented in Table 2 in the next section of this study.

3. Results

In this section we present the results of the statistical and econometric analyses to estimate the determinants that affect consumers' attitudes toward corporate environmental friendly practices. From the sample of 464 consumers in question, 60.1% were women and 39.9% men. Most consumers had completed secondary education (45.7%), 33% were university-educated and 16.8% had a master degree. As regards their age, most respondents were between the ages of 30 and 40 years (32.6%); 22.8% were between 18 and 25 years, 78.6% between 41 and 50 years and the rest above 50 years. 42.0% of consumers were married. The consumers' average monthly private, non-property-related, income was €740.00. The income of 25.0% of consumers varied between €750 and €1.000 and 33.6% of consumers' declared income no higher than €500. However, 14.9% of consumers declared having an income above €1250. A 47.6% of the respondents reported that they were aware of socially responsible enterprises that operate in Greece and 35.1% could name a socially responsible company aiming at environmental friendly practices. From the sample of consumers in question, 21.3% had previously sought information on CSR dimensions. As for the perceived level of communicating CSR activities, only 7.5% of consumers replied that totally agree with the statement "There is sufficient information about the socially responsible actions of a company", whereas 35.3% replied "disagree" and 24.6% "totally disagree".

The majority of the respondents (53.9%) participated in environmental friendly actions and 70.9% strongly believed that companies should adopt environmental friendly production practices to minimize the environmental damage they cause. Consumers were asked about their buying habits toward products which were made from companies that encompass environmental activities in their CSR plan. Regarding the question "Can you tell us, how important is the following criteria for choosing a product" the majority of respondents (73.1%) reported that price is an important (38.6%) or very important (34.5%) criterion for choosing a product and 38.3% replied that advertising is less important criterion. In addition, about half of the consumers (45.9%) answered that product quality is a very important buying criterion and only 1.1% answered that quality is not important at all. Almost one out of two (53.9%) of the consumers did prefer to buy products of services from a socially responsible company targeting environmental protection, 31% of the respondents were neutral and the rest disagreed with that option. Finally, 57.8% of the consumers were willing to pay more for products made from a socially responsible company given that price and quality is equal.

Several interesting results were obtained from the empirical estimation of Eq. (1) and (2). Table I presents the results of the fitted binary logistic model with respect to consumer's awareness of a company's socially responsible activities focusing on environmental protection. The results of the fitted ordered logistic model with respect to the level of consumer's preference toward companies that encompasses environmental activities in their CSR plan are presented in Table II

As follows from Table I, the variable "income" is statistically insignificant. Contrary, the variable "age" is statistically significant at a 1% level. In particular, the coefficient of "age" is 0.16 and the relative risk of this particular variable is 1.174, which implies that the corresponding percentage change is 0.174. This means that in relation to age the odds of consumers' awareness toward a company's environmental responsible activities increase by 17.4 per cent ceteris paribus. Given the estimated coefficient of the variable "age2", consumers' awareness of corporate environmental responsible actions reaching a maximum at 40 years of age

$$\frac{\partial\left(b_1 "AGE" + b_2 "AGE2"\right)}{\partial "\mathrm{AGE}"} = b_1 + 2b_2 "AGE" = 0.16 + 2*(-0.002)*"AGE" = 0$$

. A similar result was reported by Tian et al. (2011). In the case of educational level, result implies that the corresponding percentage change is 0.934. This means that in relation to highly educated groups of consumers the odds of consumer' awareness to CSR actions focusing on environmental protection increases by almost 0.934 per cent all other remaining fixed. In case of "gender" results imply that women rather than men have increased probability by almost 27.1% to be aware of companies that adopt environmental responsible activities, ceteris paribus. These results are in line with those by Youn and Kim (2008) whose research indicated that women and higher-education groups are more supportive of company's socially responsible actions. Similarly, the odds of consumers' awareness of environmental friendly companies increase by 0.284 and 2.525 in relation to consumers' general eco-friendly attitudes and past information about CSR dimensions, respectively. Both, "envir" and "icsr" are statistical significant at a 1% level.

The Nagelkerke R square which is a measure of predictability of the proposed model is equal to 0.207. The log likelihood statistic is quite high, rejecting the null hypothesis and concluding that at least one of the estimated coefficients is different from zero. Finally, the Hosmer and Lemeshow value equal to 4.12, with significance equal to 0.721.

The parameters of the ordered probit model were estimated by maximum likelihood estimation. Estimation results are shown in Table II. First, the main focus of this discussion is the interpretation of the statistical significance of the independent variables. The changes in the probability levels of the dependent variables are also estimated, which provides an interpretation of the substantive effect of the independent variables. This allows one to interpret changes in the probability of the agreements levels for a change in a given parameter, relative to the reference case. As shown, in the second column of Table II, in the case of consumer's socioeconomic variables, all the variables are statistically significant in 0.01 levels, other than income.

Table 1: Estimated binary logistic regression of consumer's awareness of a company's environmental responsible activities (yes: 1 no: 0)

Independent variables	Estimated Coefficients	Odds Ratio	$e^{\beta' 1}$ - 1
Constant	4.62*** (4.24)	-	-
gender	0.24** (2.10)	1.271	0.271
age	0.16*** (2.77)	1.174	0.174
age2	-0.002*** (-2.72)	0.998	-0.002
education	0.66*** (2.83)	1.934	0.934
income	0.26 (0.23)	1.297	0.297
envir	0.25*** (2.70)	1.284	0.284
icsr	1.26*** (5.01)	3.525	2.525
Log likelihood	-260.821		
Nagelkerke R^2	0.207		
Hosmer and Lemeshow	4.12 (0.721)		

Note: ***, ** represent levels of significance at 1% and 5%, respectively. Z statistics are presented in parentheses.

Similarly, the variables "advertisement" and "price" are not statistically significant. In particular, results imply that an increasing positive correlation exists between level of agreement to prefer products of environmental responsible firms (called thereafter: PERC) and age profile. Each addition year of age is associated with 5.5% (OR=1.055) increase in the odds of reporting agreement in relation to PERC, when all other values held constant. Females are more likely to prefer buying PERC compared with men. The odds of reporting preference to PERC are 1.64 times greater for female in comparison to men. Further, an increasing positive correlation exists between level of agreement to buy PERC and educational attainment. This means that in relation to highly educated groups of consumers the odds of agreement to buy PERC increase by almost 12% (OR=1.123) all other remaining fixed. Similarly, the odds of consumers' agreement to buy PERC are higher by 2.256 and 1.46 times in relation to consumers' general eco-friendly attitudes and past information about CSR dimensions, respectively. Further, an increasing positive correlation exists between level of agreement to buy PERC and the importance of quality as a purchasing criterion. Finally, consumers' who are willing to pay more for products from a socially responsible company, given that price and quality is equal, are more likely to prefer buying PERC rather than non-willing consumers. The odds of reporting agreement to buy PERC are 3.59 times greater for persons who are willing to pay more for products from a socially responsible company, given that price and quality is equal, in comparison with others, ceteris paribus.

Table 2: Estimated ordered logistic regression of consumer's preference to buy products from environmental responsible companies (disagree: 1, neutral: 2, agree=3).

Independent variables	Estimated Coefficients	Odds Ratio	Marginal Effects		
			Disagree	Neutral	Agree
gender	0.494*** (2.17)	1.639	-0.023	-0.098	0.121
age	0.0538*** (4.52)	1.055	-0.0024	-0.011	0.0132
income	-0.0002 (-0.87)	0.999	0.0001	0.00004	-0.00005
exmoney	1.374*** (5.93)	3.590	-0.071	-0.257	0.328
education	0.641*** (2.87)	1.123	-0.005	-0.023	0.028
envir	0.814*** (3.41)	2.256	-0.0430	-0.157	0.199
advertisement	0.116 (0.81)	1.898	-0.031	-0.126	0.157
price	0.166 (1.28)	1.180	-0.007	-0.033	0.041
quality	1.492*** (10.78)	4.444	-0.066	-0.299	0.365
icsr	0.383*** (2.48)	1.467	-0.017	-0.076	0.094
_cut1	5.7518 SE: 0.8645				
_cut2	8.4701 SE: 0.9284				
Log likelihood	-299.46				
Pseudo R^2	0.34				
LR chi2	308.37 (0.000)				

Note: ***, ** represent levels of significance at 1% and 5%, respectively. Z statistics presented in parentheses.

The marginal effects show that women are more likely to prefer to buy PERC than men. Similarly, being highly educated, well informed about CSR actions and eco-friendly consumer increases the odds of reporting agreement to buy PERC and decreases the probability to report disagreement.

Table III presents the predicted probabilities of Y for each category when all explanatory variables are set to their mean value. So, for all average values, the probability that a consumer is disagreeing to prefer buying products from environmental responsible companies is 4.7%, to be neutral 38%, and agreeing 57%.

Table 3:. Predicted probabilities for Y (disagree: 1, neutral: 2, agree=3).

Predictions for Y Estimated Coefficients					95% Confidence Interval					
Pr(y=1|x): 0.0468					[0.0280, 0.0656]					
Pr(y=2|x): 0.3798					[0.3208, 0.4389]					
Pr(y=3|x): 0.5734					[0.5113, 0.6354]					
Variable	gender	age	income	exmoney	education	envir	advertisement	price	quality	icsr
x=	0.601	46.27	742.86	0.575	0.692	0.707	2.638	3.028	2.905	0.562

4. Conclusions

This paper has focused on providing insights into which factors affect consumers' awareness and preference toward products and companies that adopt socially responsible activities aimed at environmental protection in Athens, Greece. For this purpose logistic regression models were estimated to identify the socioeconomic profile of the consumers that are prone to buy products that were made from environmental responsible companies. The empirical results suggest that middle-aged people and women are more likely than others to be aware of a company's CSR actions targeting environmental dimensions. This study also shows the importance of environmental awareness in the preference to buy products from environmental friendly companies. In particular, environmental awareness is strong, statistically significant, factor that positively affect consumers' agreement as a buyer of CSR environmental products. Further, it is estimated that income is not a predicted variable of awareness of corporate environmental friendly strategies. The same hold for the case of purchasing habits for products that are made from socially responsible companies.

It is important for enhancing sustainable development that consumers consciously adopt sustainable consumption lifestyles. As consumers become more sustainable consumers, the negative impact of their choices on environment is minimized. In this context, investigating the socioeconomic profile of consumers would have multiple useful economic and environmental policy implications. In particular, in the business sector, entrepreneurs could expand their market share by focusing their advertising campaigns about CSR environmental actions on those less CSR positive consumers. On the social level, if companies realize the motives of producing products under environmental friendly conditions, can not only improve their financial performance but also contribute to environmental protection. However, further research is needed to achieve this goal. Specifically, this study provides information that retailers and marketers can use when seeking to connect with consumers in Greece via CSR environmental activities. However, there must be an emphasis on the various aspects that form a CSR environmental friendly buying attitude or level of awareness rather than relying solely on self-reported intentions on the part of consumers. An understanding of consumer choices of CSR at the firm level is important in the development and implementation of successful CSR programs and enhancement of sustainability.

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Corporate Social Responsibility and Environmental Management Policies in Higher Education

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Abstract
During the last two decades, a new business philosophy and an innovating way of operating has grown of great interest and has been an issue of vital importance, both in the business world and in academia. This concept is known as Corporate Social Responsibility (CSR). The purpose of this paper is to investigate how students perceive CSR and its added value concerning the environmental management and protection. For this purpose, a field research has been conducted, addressed to students of Greek Higher Educational Institutions. Some of the findings derived are that there are differences in the perception of CSR and also a significant percentage of the sample connects CSR practices with the environmental protection. Furthermore, it has been noticed a surge for change and implementation of CSR subjects from the part of Higher Educational Institutions. Finally, certain proposals have been made from the students' part so as to help future generations preserve and protect the environment.

Keywords: Corporate Social Responsibility (M14); Sustainability (Q56); Higher Education (I23).

1. Introduction

During the last decades, there has been a continuous growing interest in a new business philosophy, known as Corporate Social Responsibility (CSR) (Dam & Scholtens, 2007; Becchetti et al., 2005; Beltratti, 2005; Hancock, 2005). Organizations of the corporate world but also Higher Education Institutions (HEI) have embraced CSR and also to a large extent, HEI have introduced courses concerning CSR and business ethics in their curriculum. The main reason was because they have identified the need and the importance of proper students' education on social, ethical and environmental issues, so they are equipped with the necessary knowledge, perceptions and behaviors for their careers.

However, the question that emerges from the above is whether the Greek reality has followed or has adopted the corresponding actions. Due to limited-minimum Greek literature that exists on CSR and Higher Education, it is almost impossible to conduct reliable and valid conclusions about Greece. Thus, it was imperative a study to investigate the matter in Greek HEIs.

2. Define CSR

Despite the fact that the term of Corporate Social Responsibility is contemporary, its concept and content exists from centuries ago. The roots of Corporate Social Responsibility can be traced in the depths of time. Corporate responsibility is diffused through the centuries and took various forms and names such as donation, sponsorship, charity and cooperation (Mueller, 2009; Smith, 2003; Carroll, 1999; Fitch, 1976; Garriga & Mele, 2004; Sohn, 1982; Gray, 2001; Rahman & Momin, 2009; Gray, 2002; Mathews, 1997; Owen, 2008; Parker, 2005)

Nowadays, the meaning and content of CSR is complex (Amaeshi & Adi, 2007; Okoye, 2007). There are plethora definitions about CSR and it is common phenomenon that many of them are contradictory towards certain issues (Van Marrewijk, 2003).The most widely used and commonly accepted definition is that of the European Commission (2011) that defines Corporate Social Responsibility as “the responsibility of enterprises for their impacts on society”. Furthermore, to fully meet their social responsibility, enterprises “should have in place a process to integrate social, environmental, ethical human rights and consumer concerns into their business operations and core strategy in close collaboration with their stakeholders” Therefore, there is a direct and interactive relationship between CSR and environmental protection and management.

3. CSR and higher education

Corporate Social Responsibility is not only a theory and an idea but it has been discussed in the literature for more than half a century (Davis, 1973). But in the recent years the concept of CSR has come in academia and in other disciplines (Dentchev, 2005). The need of CSR started from the 1970s, which can be characterized as a period of "moral crisis." At that period, business education was delivered in a way that emphasized the economic and not the relational implications, giving special attention to short-term profits so that organizations would be profitable, regardless of the consequences on the environment and society. Therefore, the fact that there was a focus on financial concerns and students were educated in individualistic ethics, emphasizing self-interest and materialistic gain. Environmental problems such as climate change, consumption patterns, and environmental degradation have been underrepresented by traditional environmental education (Huckle, 1999; Gough & Scott, 1999; Ghoshal, 2005; Pfeffer, 2005; Giacalone, & Thompson, 2006).

As everyone realizes, scandals and the lack of moral and interest for environmental protection were at their peak. Thus, the academic community reacted and started to change way that education was being delivered because they have observed that through moral attitudes and behaviors, organizations would achieve maximize profits. So, HEI worldwide have alter their way of operation so that the future workforce would be proper educated and to implement basic principles in business operational activities (Hartman & Hartman, 2005; Rossouw, 2002; Sims & Brinkmann, 2003; Sims, 2000; Weber, 1990)

Thus, the academic community has introduced courses concerning business ethics and environmental management in the curriculum. The result of this movement is that business ethics has experienced exceptional boom in the field of Higher Education and similar courses became more well-known and attractive at both undergraduate and postgraduate level. Christensen et al (2007) observed that 42% of the best MBA programs have incorporated courses on CSR (Salmaus, 1987; Vogel, 1987; Christensen et al, 2007).

Numerous articles have been written about CSR education in Higher Education and they focus on how CSR is integrated into academic curricula and the way that is incorporated in universities (Alvarez & Rogers, 2006; Bradbury, 2003; Down, 2006; Fien, 2002; Kevany, 2007; Lourdel, 2007; Moore, 2005; Posch & Steiner, 2006).Throughout the academic filed, a lot of universities have introduced courses in their curriculum regarding the environmental protection, environmental ethics, social responsibility and many more. An indicative example of what is happening throughout the globe are universities in China (Niu et al, 2010), in Russia (Lindroos, 2001), in Jamaica (Down, 2003, 2006) along with Austria and Sweden (Anderberg et al, 2009).

Many HEI sectors and departments have implemented CSR. Illustrative examples of such departments are mechanical engineering, information technology, architecture, tourism, etc. (Fien, 2002; Down, 2006; Wright, 2003). Also, International Schools of Business Administration have begun to implement social, responsible initiatives to educate future leaders, managers and employees in order to prepare them to face environmental, social and economic systems throughout their careers and crucial issues around these areas (Deale et al, 2009; Elkington, 1998; Savitz & Weber, 2007; Stubbs & Schapper, 2011).

Moreover, there have been extending discussions about whether CSR should be taught as a separate course in the curriculum or if you need to create a new program that will support the basis of the concept and content of CSR (Christensen et al, 2007; Rusinko, 2010). The most interesting thing is to investigate whether or not, the same thing is happening in Greek universities and other institutions of higher education.

4. CSR educational importance for students

Organizations along with universities have an obligation towards society and the environment (Alshuwaikhat & Abubakar, 2008; Haden et al, 2009). There is no institutional framework or strategy that obligates academic institutions to promote and introduce education on Corporate Social Responsibility. However, there are some initiatives and declarations such as the United Nations and the European Union concerning the dissemination of CSR in academic field. There have been mapped such actions like the Declaration of the United Nations' Decade of Education for Sustainable Development (DESD) 2005-2014 which indicates the opportunity for Higher Education Institutions to promote education and awareness for a sustainable future. Also another similar action is the United Nations Conference on Environment and Development (1992), which proclaimed the promotion of education, information society in Social Responsibility.

Several international conventions and protocols have been made in order to face environmental and sustainability issues. We can point out the most important of them, such as the Montreal Protocol on substances that deplete the Ozone Layer (1987), the United Nations framework convention on Climate Change (1992), the Kyoto Protocol to the United Nations framework convention on Climate Change (1997), the Convention on

Biological Diversity (1992), the Cartagena Protocol on Biosafety to the convention on Biological Diversity (2000), and the Stockholm convention on Persistent Organic Pollutants (2001). In general, there can be found more than 400 agreements on environmental issues.

However, because of the fact that in most countries there is no institutional framework that requires agencies to be more responsible, all best practices and actions have been performed in means of voluntary initiatives. The same also applies in the case of Higher Educational Institutions. A survey by Nejat et. al (2010) shows the effects and benefits of CSR integration for the top 10 universities worldwide. The education provided focuses on vital CSR issues such as transparency, reliability, human rights, labor rights according to norms and laws, the protection and preservation of the environment, etc. (Nejat et al, 2011)

During the economic and ethical crisis, environmental protection's awareness becomes more and more necessary for students (Knights & O'Leary, 2006; Sims & Felton, 2006). Shareholders expect from all kinds of organizations to implement, perform and formulate social and environmental criteria and not only economic efficiency (Mitchell et al, 1997). For these reasons, it is imperative that the students' education on issues regarding CSR is critical so that they have the necessary knowledge, skills and abilities to cope with the changing market needs. Institutions of Higher Education have a very important role to play. They should investigate the needs and market trends and try to adapt their curriculum properly so as to provide the necessary knowledge to academics but also to shape an appropriate behavior and culture on social, environmental and ethical responsibility.

HEI staff and especially professors should provide to academic citizens, not only the skills and training they will need in their careers but they should make them understand how crucial and vital is decision making within an organization. Every wrong and right decision made has its own impact in. Students are going to be future managers, CEOs and future employees in general and there are going to be responsible for the shaping of business principles, values, policies and strategy which should be sustainable, socially, ethically and environmentally responsible (Lamsa & Sintonen, 2001).

5. CSR in the Greek higher education institutions

A very encouraging fact is that Greek HEI have introduced courses concerning business ethics, environmental management and CSR into their curriculum, following the trends and needs at an international level. The initial step was made mainly by Greek Schools of Economics and Business Administration, which have implemented courses, first in post-graduate level and then in undergraduate level. Some indicative examples of Greek HEI are demonstrated in the next table:

The main question that arises is if the introduction of these subjects has contributed to environmental protection in Greece and if Greek HEI's students have altered their way of thinking and operating. To reach to a conclusion, a survey was conducted from an indicative sample of Greece HEI's that have implemented courses about CSR.

Department	HEI	Course	Educational level
Business Administration	T.E.I. of Central Macedonia	Business Ethics and CSR	undergraduate
Business Administration	Eastern Macedonia and Thrace Institute of Technology	CSR	undergraduate
Business Administration	T.E.I. Athens	Business Ethics and CSR	undergraduate
Administration of Health Units and Welfare	T.E.I. Athens	Environmental Management and Public Health	undergraduate
Business Administration	University of Piraeus	Business Ethics	undergraduate
Marketing and Communication of New Technologies	Economic University of Athens	CSR	postgraduate
Human Resources Management	Economic University of Athens	Internal Communication and CSR	postgraduate
Accounting and Finance	University of Macedonia	Action Plan for the Development of CSR",	undergraduate
Marketing and Operations Marketing	University of Macedonia	CSR	undergraduate
Communications, Media and Culture	Panteion University	Social Issues and Business Practices" along with "Business Ethics"	undergraduate
Accounting and Finance	Economic University of Athens	Business Ethics	undergraduate
Marine and Business Studies	Aegean University	Business Ethics	undergraduate
	The National Technical Metsovion University	Environment and Sustainable Developmen	undergraduate
Civil Engineering	Aristoteleion University of Thessalonica	Environmental Protection and Sustainable Development	postgraduate
International and European Studies	Panteion University	Environmental Governance and Sustainable Development	postgraduate
Environment	Aegean University	Environmental Policies and Management	interdepartmental graduate

6. Research

The research took place during April - December 2013 from various Schools of Business Administration of the Greek Higher Educational System but our sample was mainly from TEI of Athens and the University of Piraeus. The program used for data processing was the statistical program SPSS17.0 and the analysis presented below is used the descriptive statistics. The survey involved 220 students, of which 76 individuals were male (34,5%) and 144 were female (65.5%).

The respondents were asked if they have knowledge of CSR meaning. 87.7% answered positively, while only 12.3% responded negatively. Also, 41.5% of them knew the meaning of CSR from their educational institution. These findings are particularly interesting because students seemed to already have a first contact of this new way of business operation and Greek HEI have contributed to this fact by introducing courses about CSR.

Furthermore, 96% of the sample believes that CSR is one of the most important subjects for their academic and professional development and 90.4% supports that CSR courses have helped them in the development of responsible behavior. It is remarkable to note that 93.7% of the sample argues that a key aspect of CSR is environmental perception while 97.7% states that CSR relates directly to environmental protection. Therefore, it is observed that CSR is a philosophy which emphasizes on the responsibility to society and on the protection of the environment and it contributes to Sustainable Development. Students do not consider CSR as a way or tool whereby the organization will achieve increased profits and profitability as its primary purpose.

Additionally, students were asked for what reason CSR concerns them and the results show that in the vast majority, 97.7% of them believe that as the future human resources, they should have sensitivity to social and environmental issues.

Finally, students were asked to give their personal opinions and proposals on how Greek Higher Education Institutions can contribute to environmental protection. The main recommendations that were made is the introduction of CSR courses in the curriculum so that academic citizens will shape a proper perception towards CSR and also this perception will be transmitted to academic staff and professors so that, gradually, the new philosophy is going to be applied by HEI operations. Also, students consider that HEI should implement control energy use as well as the implementation of environmental management systems (ISO, EMAS etc). An additional recommendation is the commitment of HEI for recycling and the use of recycled materials in every activity. Moreover, students suggest the planning of informative events and actions for the protection and restoration of the environment (volunteering, planting, etc) inside their university so as to inform all the academic society about the eco-friendly policies. According to the sample, these recommendations will contribute in a large degree to the integration and adoption of responsible and environmental-friendly behavior, oriented to CSR throughout the academic community.

7. Conclusions

Investigating the global literature in depth, it is worth to be mentioned the strong correlation between the concept of CSR and the environmental protection. The need of CSR philosophy was emerged mostly after the 70' in order to confront crucial issues such as environmental scandals, the Climate Change, the Ozone Layer, the protection of biodiversity and to constrain the environmental degradation. Thus, Higher Education

Institutions introduced subjects concerning Business Ethics, then Sustainable Development and nowadays CSR, in many academic fields but mostly in Business Administration, first at undergraduate level and then at post-graduate level so as to introduce and promote environmental ethics.

Greek HEI have followed the international trends and have implemented CSR courses in their curriculum so that they will educate the current generation about this concept. The survey conducted presents that almost our entire sample new the meaning of CSR and half of them from their educational area. Furthermore, they state that CSR courses are very important for the shaping of eco-friendly behavior and environmental protection. For them, it is more than just another subject but a way of completely altering their existing way of performing and decision making. They argue that CSR is not an issue that concerns the corporate world but it is a greater idea that everyone has to embrace.

Some of the limitations of the survey were the small sample and the few participated HEI Mainly, it involved two Greek Higher Education Institutions, both in Business Administration area). In the near future, the survey is going to be extended in more Greek HEI, so that more reliable data and results will be derived, presenting the actual condition in Greece. Moreover, it is going to be investigated the proportion of students that are willing to get employed in organizations that perform CSR actions, conduct sustainability reports or CSR reports and have embraced the concept of CSR. One final field of investigation is whether students will prefer postgraduate programs about CSR and if they believe that they are going to be value-added in their business career. The encouraging fact is that CSR is well-accepted for both students and Greek HEI and is an idea and philosophy whose time has come.

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Environmental policy and CSR: How climate change is interpreted in CSR reports of Greek companies

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Abtract
The environmental policy and Corporate Social Responsibility are two notions of high importance for enterprises and nations. Numerous pages have been written about the environmental policy of companies in their CSR reports. Whether it concerns to raise environmental awareness among their employees or local communities or to give in detail their environmental footprint at the end of the story it is about giving proofs of their environmental policy. Climate change is among the topics of CSR reports and is under examination in this paper. A case study analysis will be applied in order to present how climate change is interpreted in the CSR reports of Greek companies from the petroleum refining industry.

Keywords: Climate change; CSR reports; environmental policy; awareness.

1. Introduction

Climate change is a de facto reality and although each of us contributes to this reality it is common to put the blame on enterprises especially those multinationals of heavy industry. Enterprises nowadays could claim that have proofs that are or becoming green and do their best to mitigate their effects on the environment as well as support their local community economically, socially and environmentally. This attitude by enterprises is welcomed as Corporate Social Responsibility. The understanding of the role of enterprises besides seeking profit (Friedman, 1970) and cover the three dimension of CSR is obvious to anyone from local authorities, consumers, employees or investors. One of the first academics that supported CSR is Caroll (1991) who recognized the economic, legal, ethical and philanthropic components of enterprises. These components are what communities demand from corporations. Philanthropy is considered by Caroll as a prerequisite and not obligatory from what communities and the public expects from enterprises and makes a metaphor by characterizing philanthropy as the icing on the cake. The structure of the research contains: a brief introduction about Corporate Social Responsibility and how it is connected with environmental management; the connection between climate change and CSR; the analysis and conclusions. The reason why these companies were selected is that they are the only large companies in the petroleum refining industry in Greece.

The added value of this article is that enriches the existed bibliography about climate change and CSR and provides information about an industrial sector that although activates in a period of economic crisis it provides case studies and evidence that CSR could be implemented during difficult times.

2. Climate change and CSR

Climate change is unwelcome news …… (Socolow, 2006)

Meeting the challenge climate poses has the potential of addressing many other challenges as well: water and food shortages, threats to species extinction, displacement of people by rising seas and the spread of tropical diseases. Although the challenge is complex, it must be addressed now. There is no time for inaction because climate change is already happening with severe changes happening already in our planet. More specific there are three global feedback mechanisms which push the earth into a period of rapid climate change even before the two degree C limit is reached; meltwater altering ocean circulation, melting permafrost releasing carbon dioxide and methane and ice disappearing worldwide (Carey, 2012). “Two degrees” is shorthand for a precise objective: the goal is to limit the rise of the average surface temperature of the earth to two degrees Celsius, relative to a time before the Industrial Revolution.

Activities oriented to environmental protection or towards what society needs are covered by the legitimacy theory. Legitimacy theory means that when a company performs social responsibility activities (in many cases on a voluntary basis), it actually seek for the legitimacy of their existence in the eyes of the society (Hossain, Chowdhury, 2010). In that terms CSR is a very popular topic for companies and CSR reports are their vehicle to their legitimacy existence. Various issues arise when discussing about CSR activities and one of these topics will be the environment in this research. Environmental issues are on top of the agenda for governments, the public, companies, media etc. How each of them approach and analyze the problems that arise from the contaminated human activities is different.

Companies use the Corporate Environmental Management when handling environmental issues. The green model of Corporate Environmental Management is based on three stages. The first is pollution prevention which means minimizing or eliminating waste before it is created. Second is product stewardship which is related with the full life cycle of a product form the design to its use and finally its disposal. Third is clean technology which leads to development of new technologies and innovation that support sustainability (Lawrence et. al., 2005).

This green model of CSR means in other words that the industries should change and must rethink the way they operate. Although heavy industries are difficult to respond to climate change at least they could response through adaptation. This is to anticipate harm to natural and human systems and plan an adaptive response to lessen the vulnerability of people, their property and the biosphere to coming changes. Then try mitigation response which is to lesser the rate of emissions added to the atmosphere (Wright, 2005). The companies of heavy industry need to address environmental problems with managers well educated about CSR issues and strongly motivated to the principles of Environmental Management.

Business education traditionally addresses corporate social responsibility from a variety of perspectives like (1) financial benefit to the firm and shareholders by attracting socially responsible investors, minimizing regulation, improving brand image, and improving returns through an image of corporate social responsibility; (2) avoidance of “sin stocks” (deontological motives) by concerned investors; (3) activist investors seeking to “reward good behavior and to provide an incentive for firms with lagging social performance to improve”; and (4) consumers and investors who “use their power” for self- expression (Rockwood, 2008). Climate change case according to Rockwood could be used effectively to discuss corporate social responsibility from each of these perspectives. It is also the author’s view that business education has a critical role to play in educating tomorrow’s business leaders to recognize their ethical obligation to address climate change simply because it is a task that has to be performed.

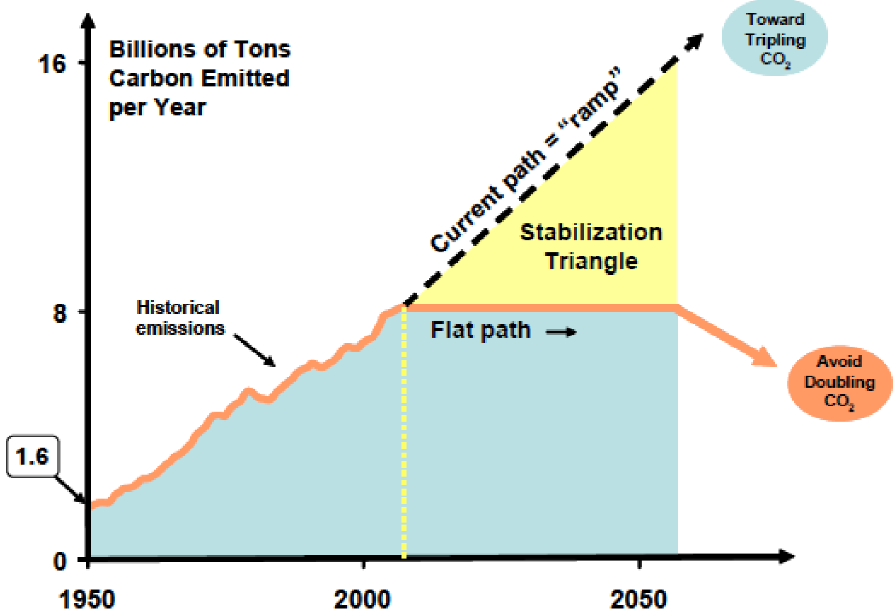
Educating future managers in order to implement green CSR activities is a topic that should be discussed in the academic literature of CSR and environment. There are certain steps for Environmental Management and involve managers committed to sustainability, line managers and workers cooperation and involvement, codes of environmental conduct and cross functional teams which are individuals by different departments of the company. The key to a successful Environmental Management is partnerships and involvement from the bottom to the top with committed and educated people about environmental issues.

Environmental CSR is reflected through green voluntary activities implemented mainly by the private business sector (not necessarily) in order to adapt and mitigate their harmful impact on society and become true stewards for the society.

An example of mitigation on environmental issues comes from Socolow and Pacala who tried to educate firms on how to solve environmental pollution created by industries. Figure 1 and Figure 2 describes the Carbon Mitigation Initiative. The Carbon Mitigation Initiative is a joint project of Princeton University, BP, and Ford Motor Company to find solutions to the greenhouse gas problem. Socolow and Pacala created the concept of stabilization wedges: 25-billion-ton “wedges” that need to be cut out of predicted future carbon emissions in the next 50 years to avoid a doubling of atmospheric carbon dioxide over pre-industrial levels. The “stabilization wedges” concept is a simple tool for conveying the emissions cuts that can be made to avoid dramatic climate change. Two scenarios are applied in this scheme. The first scenario leads to global warming if emissions double for the next 50 years and the second scenario could keep emissions flat for the next 50 years and then work to reduce emissions. This emissions saving is called stabilization triangle. CMI set out to quantify the impact that could be made by a portfolio of existing technologies deployed on a massive scale. To make the problem more tractable, we divided the stabilization triangle into eight “wedges.” A wedge represents a carbon-cutting strategy that has the potential to grow from zero today to avoiding 1 billion tons of carbon emissions per year by 2060. The wedges can represent ways of either making energy with no or reduced carbon emissions (like nuclear or wind-produced electricity), or storing carbon dioxide to prevent it from building up as rapidly in the atmosphere (either through underground storage or biostorage). Keeping emissions flat will require the world’s societies to “fill in” the eight wedges of the stabilization triangle.

This scheme could be adapted by enterprises as well as public authorities in order to educate their workforce and become motivated on environmental issues.

Figure 1: Stabilization triangle and Stabilization triangle



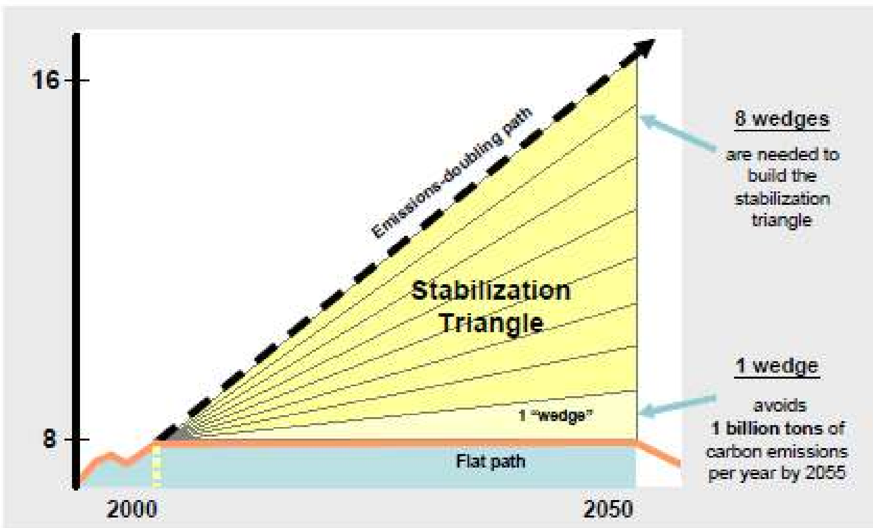


Figure 2: Stabilization wedges in order to cut Carbon by Socolow and Pacala (2006)

Stabilization Wedges – 15 Ways to Cut Carbon

= Electricity Production, =Heating and Direct Fuel Use, =Transportation, = Biostorage

Strategy	Sector	Description	1 wedge could come from...	Cost	Challenges
1. Efficiency – Transport		Increase automobile fuel efficiency (2 billion cars projected in 2050)	... doubling the efficiency of all world's cars from 30 to 60 mpg	\$	Car size & power
2. Conservation - Transport		Reduce miles traveled by passenger and/or freight vehicles	... cutting miles traveled by all passenger vehicles in half	\$	Increased public transport, urban design
3. Efficiency - Buildings		Increase insulation, furnace and lighting efficiency	... using best available technology in all new and existing buildings	\$	House size, consumer demand for appliances
4. Efficiency – Electricity		Increase efficiency of power generation	... raising plant efficiency from 40% to 60%	\$	Increased plant costs
5. CCS Electricity		90% of CO_2 from fossil fuel power plants captured, then stored underground (800 large coal plants or 1600 natural gas plants)	... injecting a volume of CO_2 every year equal to the volume of oil extracted	\$\$	Possibility of CO_2 leakage
6. CCS Hydrogen		Hydrogen fuel from fossil sources with CCS displaces hydrocarbon fuels	... producing hydrogen at 10 times the current rate	\$\$\$	New infrastructure needed, hydrogen safety issues
7. CCS Synfuels		Capture and store CO_2 emitted during synfuels production from coal	... using CCS at 180 large synfuels plants	\$\$	Emissions still only break even with gasoline
8. Fuel Switching – Electricity		Replacing coal-burning electric plants with natural gas plants (1400 1 GW coal plants)	... using an amount of natural gas equal to that used for all purposes today	\$	Natural gas availability
9. Nuclear Electricity		Displace coal-burning electric plants with nuclear plants (Add double current capacity)	... ~3 times the effort France put into expanding nuclear power in the 1980's, sustained for 50 years	\$\$	Weapons proliferation, nuclear waste, local opposition
10. Wind Electricity		Wind displaces coal-based electricity (10 x current capacity)	... using area equal to ~3% of U.S. land area for wind farms	\$\$	Not In My Back Yard (NIMBY)
11. Solar Electricity		Solar PV displaces coal-based electricity (100 x current capacity)	.. using the equivalent of a 100 x 200 km PV array	\$\$\$	PV cell materials
12. Wind Hydrogen		Produce hydrogen with wind electricity	... powering half the world's cars predicted for 2050 with hydrogen	\$\$\$	NIMBY, Hydrogen infrastructure, safety
13. Biofuels		Biomass fuels from plantations replace petroleum fuels	... scaling up world ethanol production by a factor of 12	\$\$	Biodiversity, competing land use
14. Forest Storage		Carbon stored in new forests	... halting deforestation in 50 years	\$	Biodiversity, competing land use
15. Soil Storage		Farming techniques increase carbon retention or storage in soils	... practicing carbon management on all the world's agricultural soils	\$	Reversed if land is deep-plowed later

For more information, visit our website at http://cmi.princeton.edu/wedges.

3. Methodology

The methodology chosen to analyze how climate change is translated by the three studied companies is a combination of studying the literature review and content analysis of the CSR reports and the GRI framework. GRI Guidelines is a framework used widely by companies in order to disclosure in a sustainable way their social economic and environmental information about the company's activities. According to the KPMG Survey of Corporate Social Responsibility Reporting 2013, there is a slightest increase in the percentages of CSR reporting in Greece from 33% to 43% (KPMG, 2013).

The appliance of content analysis is used in order to examine beliefs, organizations, attitudes, and human relations in sciences (Weber, 1990). Berelson (1952) defined content analysis as "a research technique for the objective, systematic, and quantitative description of manifest content of communications". Content analysis is chosen because it offers a systematic and reliable way to code and categorize the existed data by compressing quantitive and qualitive data into categories based on explicit rules of coding. It has the attractive features of being unobtrusive, and being useful in dealing with large volumes of data (Stemler, 2001).

Another nonfinancial reporting assessment has been developed as a benchmark tool for examining reports on the basis of their inclusiveness and other factors by the Centre for Environmental Policy and Strategic Environmental Management at the University of the Aegean. The assessment methodology relies on the GRI 2002 reporting framework. The vision and strategy of the reporting organization on sustainable development, including a relevant statement by the CEO or equivalent senior manager, a profile of the organization giving information about their activities, the management systems and policies regarding sustainable development and the performance of the organization during the report period about the triple bottom line with quantitative and qualitative indicators are the clusters of criteria and indicators of GRI guidelines. In Figure 3 the scorecard gives an example of how the scoring system methodology is applied (Skouloudis and Evangelinos, 2009).

Exhibit 2. Applying the Scoring System Methodology

Score	Scoring Levels	Example: Direct CO_2 Emissions
0	No Mention	No relevant information provided in the report.
1	Generic Statements	"We monitor our CO_2 emissions."
2	More Detailed Information	"In 2006, the company's total emissions of CO_2 were equivalent to 800,000 tonnes."
3	Extensive Information	"Our head offices and plants in Greece produced 500,000 tonnes of CO_2, while the rest of our abroad operations resulted in 300,000 tonnes of CO_2."
4	Full and Systematic Coverage	"In 2006, the company's total emissions of CO_2 were equivalent to 800,000 tonnes. Our head offices and plants in Greece produced 500,000 tonnes of CO_2, while the rest of our abroad operations resulted in 300,000 tonnes of CO_2. This is a 5% reduction from last year's emissions. It is our stated commitment to reduce our CO_2 emissions by a targeted 10% by the end of 2008, compared to our 2004 level."

Figure 3: Example of the scoring system (Skouloudis, Evangelinos, 2009)

Many academic papers have studied how companies publish their CSR reports in order to find out how companies deal with specific topics (environment, human resources, society etc). The methods used to identify the attitude of companies toward a specific topic or the whole CSR concept are various and based either on numeric data (rarely) or qualitative data.

Băleanu in their paper examines the way one hundred Romanian companies publish CSR by searching the companies' websites in order to find Another paper that describes how one hundred Romanian companies engage to the concept of CSR after searching the information found in the companies' websites .Their findings reveal that the percentage of Romanian companies that practice CSR is relatively low meaning that 49 from the companies have at least one section on their corporate website dedicated to corporate social responsibility. As far as the existence of separate CSR reports only 10% of the Romania's companies publish at least one CSR reports the last three years (Băleanu et. al, 2011).

Fafaliou et. al. examines the way Greek-owned short sea shipping companies understand the meaning of CSR. The results of their research indicate the poor dissemination of CSR concept within the shipping sector as a whole. More specific the reasons reported for not being involved in CSR activities according to the shipping companies were lack of public support or encouragement, lack of information for the implementation or no self-consciousness of CSR impact to business activity. CSR is limited to a small number of short sea shipping providers, which are either subsidiaries of international conglomerates or are controlled by entrepreneurs that are personally aware of and committed to CSR (Fafaliou et. al. 2006).

Dagilienė and Gokienė (2011) used the analysis of scientific literature and its logical generalization, the examination of separate cases of social responsibility reports of companies listed in Global Compact Network Lithuania. The results showed Lithuanian social reports are mostly oriented to presenting goals, management systems mostly using descriptive analysis.

4. Analysis

According to the scorecard of Skouloudis and Evangelinos (2009) the following table presents the environmental indicators that arouse from an in depth analysis in CSR reports of the three studied companies. The following categories represent the most common topics about the environment in the CSR reports. The score that gets each category is equal with the amount of information found in these reports which means detailed numeric data and information about the related topics.

Each company sets its goals for the environmental management and this is reflected though the introductory note at the beginning of the chapter on Environmental management.

The following messages contain in brief the principle of the company on Corporate Environmental Responsibility:

ELPE

…where our main objective is to continuously improve environmental performance and environmental protection as a key component of sustainable development.

MOTOROIL

Protection of the environment and energy-saving are among our primary concerns.

Table 1: Scoring on Environmental Indicators of CSR reports

Environmental Indicators	**ELPE**	**MOTOROIL**
Environmental policy	4	4
Environmental Management Systems	4	4
Green Investments	4	4
Climate change (CO_2 emissions)	4	4
Training on environmental issues	4	4
Natural resources	4	4
Biodiversity	3	0
Compliance with Regulations	3	3
Renewable Energy Sources and Biofuels	4	2
TOTAL	30	25

Table 2: Example of numeric data for the environmental indicators of the studied companies

	ELPE	**MOTOROIL**
Green Investments	€ 4,257 εκ	€ 676,6 εκ
Climate change (CO2 emissions)	276.216tn	1.965 ml tn
Training hours on environmental issues	1378	12500

The messages are clear and stress the attitude of corporation towards the environment as their main concern or focus or objective. Yet the only company that links their environmental performance with environmental protection as a step towards sustainable development is ELPE while MOTOROIL have a minimal message about their environmental management.

Environmental management systems are adapted by both companies. ELPE uses the certified Management Systems for Quality ISO 9001:2008, the environment ISO 14001:2004, health and Safety OHSAS 18001:2007 and ISO 17025 which concerns refineries laboratories. MOTOROIL uses the certified Management Systems for Quality (ISO 9001:2008), the environment (ISO 14001:2004, EMAS III ER 1221/2009) and health and Safety (OHSAS 18001:2007). Environmental management systems are adopted by enterprises motivated by the bottom line quest to increase productivity and as well as by government regulation. EMS appears according to a survey of manufacturing plants by to be an effective tool for managing environmental costs and risks inside and outside the factory in ways that adds to –rather than detracts from- the bottom line (Florida and Davison 2001).

The environmental indicators of investments show what companies spent on green activities in Euros. The training show how many hours were spent for seminars on environmental issues to personnel, public and other groups. Natural resources are environmental indicators covering usually in CSR reports several aspects of the company's environmental management. Waste management, recycling, water management, air emissions, noise management are several topics that cover the chapter of natural resources. Each of these topics is analyzed either in detail with numeric data or with detailed text information about specific green activities. According to GRI Guidelines both companies cover the EN indicators about natural resources with numeric data.

MOTOROIL covers the different issues of natural resources as separate chapters and provides numeric or graphic data along with detailed text information. ELPE before analyzing the chapter of natural resources provides a brief message ... *to minimize the impact of our activities on the natural environment, including reusing water, waste recovery, protecting biodiversity and reducing gas emissions* and then provides numeric and graphic data along with text information.

Biodiversity is covered as a separate chapter only for ELPE while for MOTOROIL there are there are no protected or restored habitats as EN13 states in GRI Guidelines. The compliance with regulation is mentioned in the reports of MOTOROIL and ELPE. Both companies make reference about REACH regulation.

Both companies have measured the total training hours spent on environmental issues. It is important for companies to have educated personnel from the bottom to the top of the hierarchy so that environmental issues could be addressed properly.

Another indicator is green investments and again both companies spent money on activities that concern technology, redevelopment of their plants or improve their operation with energy efficiency programs. Finally a section about biofuels and renewable energy resources is dedicated to both CSR reports. Initiatives to produce energy-efficient or renewable energy based products and services as indicator EN6 in GRI Guidelines is updated in both industries.

Each company uses graphic and data along with per year information about their amount of their pollutions and the techniques they use in order to mitigate their impact. There is always a need for improving their CSR reports with consist data in a homogeneous way. The issue of comparability on environmental performance is mentioned in the article of Perrini (2005). The lack of common references causes the multiplication of reporting methods and units of measurement as each company presents its performance indicators from its own personal view of that the impact on the environment means. As a consequence it is difficult for stakeholders to express an objective opinion on a company's commitment towards respecting and safeguarding the environment (Perrini, 2005).

5. Conclusions

Addressing environmental issues is a challenge and needs immediate action from each of us but also from corporations. The reason that makes it so urgent is that according to Maring Manning an atmospheric scientist at Victoria University of Wellington in New Zealand and a key player in the 2007 round of the Intergovernmental Panel on Climate Change reports: The rate of change this century will be such that we can't wait for the science (Carey, 2012). In these sense corporations need to be consistent and organized when implementing activities oriented to reducing their environmental impact on earth. Humanity faces a choice between two futures: doing nothing to curb emissions (which pose huge climate risks) and bringing them under control (which has costs but also benefits) (Socolow, Pacala, 2006).

The approach of reducing the pollution described as regulation by publicity or regulation by embarrassment. The US government encourages polluting less by publishing information about the amount of pollutants individual companies emit each year. In many cases, companies voluntarily reduce their emissions to avoid public embarrassment (Lawrence et. al., 2005).

The bottom line from the brief analysis on these two CSR reports is the fact that although they develop a satisfactory environmental CSR strategy yet in the field of CSR there are more. One of these is the creation of partnerships with the state, the public, universities and other bodies that could contribute to reducing the environmental impact of industries like the refinery sector. One thing was not mentioned purposely and this is the fact that those companies have received many times bad criticism when developed green activities characterizing greenwash but the truth is that the authors intention was to give a positive feedback in order to promote green CSR.

McElhaney (2009) argues that when CSR is integrated in to the business strategy it could create value like the case of HP and Dell. HP is committed to recycling but Dell comes along with a printer and promises to plant a number of trees for each unit purchased; and Dell becomes known as an environmentally friendly company to HPs loss.

From the above brief analysis of how Greek companies report their Green CSR it is important to acknowledge their effort. For environmental issues that are complex, that require expensive remedies, or that require change across multiple firms—such as global warming—political pressure is likely to remain a critical influence on CSR activities(Lyon and Maxwell, 2008).

Further study should be given to the issues of creation of partnerships and the issue of educating young managers either in universities or inside the company on national level. Corporations in Greece could develop effective CSR strategies if they have the help of universities but also if they have educated managers on the field of CSR. A green corporation is one that operates in a consistent and responsible way with the principles of sustainable development.

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From Green Policy to Results in Greece- The Response of Greek Firms to the National Call for Boosting Green Entrepreneurship

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Abstract
This paper is a first attempt to link aspects of green policy to green results for the case of Greece by studying and examining the response of Greek firms to the national call for boosting green entrepreneurship. The analysis is based on information on those Greek firms for which government funding has been approved. Government funding in the form of national subsidies has always been a major part of the Greek economic policy and an important instrument for entrepreneurship, employment growth and regional development. Especially for boosting green entrepreneurship, the Greek government lunched three programmes, the 'Green Firm' program, the 'Green infrastructure' and the 'Relocation' program. Four years after the official call for the first two programs and few months after the call for the third one, the majority of the firms' investments' plans have been realized or are at the stage of completion or are now implemented for the case of 'Relocation' and either recorded as new firm establishments or being integrated into the firms' production processes. Results show that the Greek entrepreneurs didn't respond sufficiently to this new reality of entrepreneurship, which compromises the desire for profitability and growth and the need for environmental protection, addressing the whole task as an opportunity and not as an obstacle neither a choice after pressure. Perhaps it is still early for the Greeks entrepreneurs to engage in such actions or maybe a different approach may be needed for their activation. In any case, the challenge of Green entrepreneurship is the challenge of the immediate future, whose framework should now be established to offer a return in the future. This should be the target of those who decide (public sector- government) and those who invest (entrepreneurs).

Keywords: Government support, green entrepreneurship, green policy, subsidies

JEL Codes: H26, L26, M13, O52.

1. Introduction

Green growth, as agreed at the fifth Ministerial Conference on Environment and Development in Asia and the Pacific, is a strategy for achieving sustainable development. It is focused on overhauling the economy in a way that synergizes economic growth and environmental protection, building a green economy in which investments in resource savings as well as sustainable management of natural capital are drivers of growth. An economy, which is in closer alignment with the sustainable development objectives, provides opportunities for using financial resources better to meet development needs and reducing the vulnerability of socioeconomic systems to environmental change and resource constraints. In this context, green growth strategies can help economies and societies become more resilient as they work to meet demands for food production, transport, housing, energy and water. Strategies can help mitigate the impacts of adverse shocks by reducing the intensity of resource consumption and environmental impacts, while alleviating pressure on commodity prices. Green growth also offers competitive advantages to those countries that commit to policy innovations. The global market for green goods and services is vast and growing fast, offering countries the dual benefit of prosperity and job creation (World Bank, 2012).

The green economy is trying to reconcile two fundamental and conflicting needs, namely those of economic development and environmental protection. In reality, however, competitiveness and environment are complementary concepts and not conflicting, as environmental protection is an essential condition for achieving strong competitiveness and, thus, sustainable economic development. In this context, green entrepreneurship is the economic activity which embraces or poses the protection of the environment and, more generally, of the nature at the center of its strategy. Green entrepreneurship asks from firms to be positive on the issue of environmental protection through their products and services as well as their production processes. The concept of green entrepreneurship identifies that the entrepreneurial milieu/ environment is part of the broader physical environment. Therefore, all natural resources, which are used in the 'real' economy, come from the earth and/or land, the air and the sea. Thus, the global reduction of the availability of the natural resources is a main limitation in the development of economic activities of this kind. Green entrepreneurship is an emerging entrepreneurship, which is closely related to the emerging green demand, to a new or revised entrepreneurial vision, as well as to the production of innovation in fields, which haven't been developed so far (OECD, 2011).

This paper is a first attempt to link aspects of green policy to green results for the case of Greece by studying and examining the response of Greek firms to the national call for boosting green entrepreneurship. The paper is structured as follows: Section one is the introductory part of the paper. Sector two presents the theoretical and empirical framework, in which the interrelated concepts of competitiveness- economic development, entrepreneurship and environmental protection are discussed. Section three describes the data that has been used and the methodology that has been followed. Section four describes the research results, which are presented at two levels: A summary table on the main features and the performance of each programme under consideration is presented at the first level. The basic firm characteristics in relation to their activities, products, employment and other information are described at second level. Finally, section five presents the main conclusions of the paper.

2. Theoretical and Empirical Evidence

Green entrepreneurship contributes into the integration of environmental cost in both the economy and the market, while highlighting the need for the implementation of a green Keynesianism alongside the global environmental governance. The fundamental characteristics of the green entrepreneurship are the following: First, the symbiosis with the special characteristics of the local economy and the ability of highlighting and enhancing those characteristics. These fundamental characteristics must be present in every case while being the base underlying all the rest. Obviously, the main characteristics and the basic priorities of the green entrepreneurship depend on the scale of the firm project under consideration. The two above characteristics, naturally, refer to the small scale green entrepreneurship. In large- scale cases of green entrepreneurship, the above factors should be taken into consideration, with emphasis, however, at the high underlying necessity of these firms. On the contrary, the emphasis in supra-national activities should be focused on their contribution in the environmental adjustment of the economy, with the smallest local environmental impacts. For example, the issue of clean energy concerns the forests, the biodiversity, and the quality of life and, thus, the product of the sustainable production of energy can be dissipated in every location (Bennett, 1991; Farinelli et al., 2011).

Obviously, the entrepreneur is the key for green entrepreneurship. The international bibliography argues that a green entrepreneur can be either making its business 'green' or simply entering a 'green' industry or expanding to a 'green' activity. In other words, green entrepreneurship could be defined in terms of the technology used for production in any sector of the economy, or in terms of the sectors, that the firms are active in, in which case the interest is focused on those parts of the economy producing specific types of output. The former is sometimes referred to as a process approach in defining green firm or activity, while the latter as an output approach. The above isn't the only definition for the green entrepreneur. In the case of incorporating ethical, social, or environmental motivations to the green entrepreneurship, then there could be different and multiple ways of defining the green entrepreneur. The following examples are some of the most representative definitions: Anderson (1998) argues that both entrepreneurship and environmentalism are based on a perception of value. The attitudes which inform environmental concern create areas of value that can be exploited entrepreneurially. In this context, 'environmental entrepreneurs' not only recognize opportunity, but construct real organisations to capture and fix change in society. Isaak (2005) introduces the term ecopreneur, referring to a person who seeks to transform a sector of the economy towards sustainability by starting business in that sector with a green design, with green processes and with the life-long commitment to sustainability in everything that is said and done. Volery (2002) splits the term ecopreneur into its two types, the first being defined as 'environment-conscious entrepreneur', who is an individual who develop any kind of innovation (product, service, process) that either reduces resource use and impacts or improves cost efficiencies while moving towards a zero waste target. The second type, called 'green entrepreneur', is the individual who is both aware of environmental issues and whose business venture is in the environmental marketplace. Such an entrepreneur pursues environmental-centred opportunities which show good profit prospects.

This paper studies the issue of green entrepreneurship by examining the response of Greek firms to the national call for boosting green entrepreneurship, as this call was expressed by the implementation of two national programs, which aimed at assisting to firms through funding them in their effort towards green growth and entrepreneurship. Government funding has always been a significant mechanism that both potential and existing entrepreneurs may use in order to start, differentiate and expand- modernize their economic activities. Government funding may take many forms and grants-subsidies are one of them. Particularly for Greece grants-subsidies have been very important for starting up, revitalizing and boosting the economy.

3. Methodology and Data

This study examines the response of Greek firms to the national call for boosting green entrepreneurship in an attempt to provide an overview of that response and a first kind of evaluation after the implementation of two programs for green growth and entrepreneurship in Greece. The Greek government launched three programs for this purpose: the 'Green Firm', the 'Green Infrastructure', and the 'Relocation' program. All of them are financed by the Operational Program for Competitiveness and Entrepreneurship (EPAE in Greek) and the Regional Operational Programs (PEP in Greek) for the five Greek regions under transition. The total budget for all three programs amounted for 70,000,000 euro, from 30,000,000 euro for the first two programs and 10,000,000 euro for the third. There was a delay in the implementation of the third program (program: relocation), which is now in progress, being in the phase of the evaluation of the proposals. Therefore, this paper focuses on the first two programs, aiming at providing an overview as well as a first kind evaluation on them.

The response of Greek firms is measured by their participation in the above two programs and this participation implies and prerequisites the following stages: The first stage is the stage of the submission of a proposal for a specific investment plan; The second stage includes the evaluation of the proposal based on specific criteria by a committee of experts; The third stage is the stage of the inclusion of the firm in the program and its public support in phases in the form of subsidy based on the submitted investment plan. In this context, the data for this study is based on the third step of the above process, when a firm is included in the program and a government document for each firm is prepared and then becomes public in the web through the program 'transparency'. However, the problem with these government documents is that they only contain the name of the submitter and this submitter could be the name of an individual or a firm, in which this individual is the general manager. Generally each government document contains the following information: The name of the submitter, the amount of the investment plan and the amount of public support which depends on several criteria, such as the region of the firm location, the main activity under consideration etc..

Methodologically, the analysis relies on collecting, elaborating and interpreting questionnaire data, which was sent to each firm and based on the following steps: Step one, all approved investment proposals in paper sheets were collected after being published in the web. Step two is focused on the construction of the first part of the database, which contains the name of the submitter (individual person with a firm or the firm name), the total budget of the proposed investment plan and the amount of public support. Step three is the step of the identification of firms based on their unique tax number, followed by the sending of a structured questionnaire to all firms under examination. The forth step is the stage of the interpretation of all structured questionnaires and the construction of the second part of the database, which includes firm data and information on the main and the secondary firm activities, the age of the firm (based on the year of establishment), the employment, financial information (capital, total assets, turnover, profits) as well as information taken from the firms' balanced sheets, the exports and the countries of their destination and the location of firms. Finally, the fifth step is the step of the elaboration of data of the second part of the database for the above fields and according to the following criteria:

Main and the secondary firm activities: The firm activities are interpreted based on the detailed structure of NACE Rev. 2 at 4 and 6 –digit level.

Age of the firm- based on the year of establishment (5 classes- time periods):

'before 1974, after 1974- before EMU', 'after EMU till the Olympic games', 'after the Olympic games- before the memorandum' and 'after the memorandum till now'.

Employment- based on the total number of employees (4 classes): 'micro, 'small, medium (50- 100) and 'medium (100- 250)'. This grouping is based on the definition of SMEs according to the EU law and particularly the EU recommendation 2003/361, which states that the main factors determining whether a firm is an SME are the number of employees (micro: <10, small: 10- 50, medium sized: 51-250), the turnover (micro: ≤ 2m. euro, small: ≤ 10 m. euro, medium sized: ≤ 50 m. euro) or the balance sheet total (micro: ≤ 2m. euro, small: ≤ 10 m. euro, medium sized: ≤ 43 m. euro).

Exports and countries of destination (5 classes for the percentage of exports and 10 regions of destination): '0-5', '5-10', '10-20', '20-50', '>50'. The classes for the parameter 'regions of destination' are determined by geographical criteria (e.g. America, Asia, Africa, Europe, and Oceania) and specific cases of interest (e.g. Balkan countries, European Union, Middle East, Northern America, and Southern Asia).

One last point should be clarified: The elaboration of data of the second part of the database is the result of and relies on the replies of the managers/ firm owners on the structured questionnaires of the firms under examination. Their overview showed that the managers/ firm owners were more willing to answer to questions on the firms' activities and their products than for exports and their firms' financial situation.

4. Results

Table 1 presents the main general features for the two programs, in relation to the number of proposals (submitted and approved), their total budget, as well as the respective amount of public support in the form of subsidy. The table also provides information on the number of firms with full data, some and no data, based on the collection of the responses of the managers and the elaboration of the structured questionnaires.

Generally, the Greek investors were more interested in the program 'Green Firm', submitting 89 proposals totally, contrary to the total number of 78 proposals for the case of 'Green Infrastructure'. However, the program 'Green Infrastructure' had a better final response, as measured by the number of the approved proposals. The figures show that this final response accounts for 70% for the 'Green Infrastructure' program and 58.4% for the 'Green Firm' case. The two programs greatly differ in the parameter of 'total budget', with the program 'Green Infrastructure' concentrating a much higher one (57,344,010.11€ and 7,270,815.47€ respectively). However, combining the data of first 'total budget', second 'amount of public support' and third the response of the Greek firms in both programs, it is obvious that the target of coverage taking into consideration the available government budget is, to a great extent, fulfilled in the case of 'Green Infrastructure' (73.4%). In contradiction, the program 'Green Firm' presented a very low percent of coverage of nearly 10%. Therefore, the interest and the participation of the Greek investors 'in the Green Firm' program were very low. In addition, the completeness of the investment plans and their compliance with the program requirements were incomplete and problematic, as criticized and argued in the final report of the evaluation committee. The response of the Greek firms in the 'Green Infrastructure' program was high enough, but the full response of the managers in the structured questionnaire was rather low: The results that follow are based on the replies of the 90% and 20% of the sample (managers) of the 'Green Firm' and the 'Green Infrastructure' programs respectively.

Table 1: The programs 'Green firm' and 'Green infrastructure' – General features

General features	Programs	
	Green Firm	Green Infrastructure
Total budget	30,000,00 euro	30,000,00 euro
Number of proposals (submitted)	89	78
Number of proposals (approved)	52	53
Total amount of budget (submitted proposals)	7,270,815.47	57,344,010.11
Total amount of public support	2,945,646.36	22,396,81.79
Coverage (%, public support/ total budget	9.8%	73.4%
Number of firms with full data	47	11
Number of firms with some data	5	39
Number of firms (with on data)	1	1

Source: Own elaboration of government data.

The program 'Green Firm' was more open, addressed in the whole manufacturing sector, from its planning and design. On the other hand, the program 'Green Infrastructure' had a more specialized orientation, focusing on the management of waste. Table 2 presents the sectoral distribution of the firms, based on their main sector of activity for both programs. Five manufacturing sectors nearly concentrate the 70% of the firms involved in the program, with the industry of 'other non-metallic mineral products' being classified first (17.65%), 'fabricated metal products' second (15.69%), 'chemicals and chemical products' third (13.83%), 'food products' forth (11.76%) and the industry 'wood and products of cork; articles of straw and plaiting materials' fifth. The first industry is further related to the activities of 'lime and plaster' and the 'manufacture of concrete products for construction purposes'. The firms of the second industry are mainly activated in the 'manufacture of doors and windows of metal' and secondarily in those of 'metal structures, 'locks and hinges' and 'treatment and coating of metals'. 'Chemicals and chemical products' are to a large extent specialized in the 'manufacture of soap and detergents, cleaning and polishing preparations', while the forth industry is further related to the activities of 'bread; manufacture of fresh pastry goods and cakes'. Last but not least, the share of 'wood and products of cork; articles of straw and plaiting materials' is equally divided between the activities of 'sawmilling and planing of wood' and the 'manufacture of other builders' carpentry and joinery'.

The sectoral distribution of the firms involved in the program 'Green Infrastructure' is clearer and to a much larger extent concentrated. The table shows that 54.72% of the investment proposals originate from firms activated in the activity 'waste collection, treatment- disposal activities; materials recovery'. Based on the content and the description of the investment plans, the above activity is further specialized in the collection of hazardous and non- hazardous waste and the recovery of sorted materials. This is due to the fact that the orientation of that program was narrower aiming at financing specific activities. This concentrated pattern also indicates that the firms involved in this program should be younger and, relatively, much younger than the firms of the other program, as the sector of 'waste collection, treatment- disposal activities; materials recovery' is a recent one, which started to concentrate the interest of potential investors after being discussed the issue of privatisation of the water resources and of the waste management on behalf of the government.

Both water resources and waste management are still activities of the public sector, administered and managed by the 3 level of local administration, namely the municipality level. However, the first announcements for their privatization have already been made, leading to the first official calls and their award to the private sector. Among the remaining industries, relatively important are the cases of 'wholesale trade, except of motor vehicles and motorcycles' (e.g. wholesale of waste and scrap) with a share of 9.43% and those of 'food products' and 'other non-metallic mineral products'(e.g. manufacture of ready-mixed concrete). It has to be noted and also clarified that, these 'remaining industries' mainly include firms with a different main activity than that of 'waste collection, treatment- disposal activities; materials recovery'. These firms, however, intend to invest in a secondary activity related to the 'Green Infrastructure' program. Based on this clarification, these 'remaining industries' involve firms in the above two industries, as well as firms in 'coke and refined petroleum products' (e.g. refined petroleum products), 'rubber and plastic products' (e.g. rubber tyres and tubes; retreating and rebuilding of rubber tyres), 'basic metals' (e.g. basic iron and steel and of ferro-alloys and lead, zinc and tin production) and firms in the civil engineering' sector, which have professional experience in public works and especially in the construction of utility projects for fluids.

Among the information and data asked and replied in the structured questionnaire were those of the age of the firm (based on the year of establishment), the size of the firm (based on the number of total employment), the exports and the countries of their destination and the firm location (based on the address of the firm). Results are presented in table 3 and summarized as follows:

The 'Green Firm' program includes much older firms, the great majority of which being established after 1974 and before Greece joining the EMU (economic and monetary union). On the contrary, 55% of the firms of the 'Green Infrastructure' program have less than 10 years of life, a fact that was implied in the previous section (sectoral analysis and distribution) and now confirmed in this section. Therefore, the firms of the two programs differ in their age, while the ¼ of the 'Green Infrastructure' case involves firms of the 'memorandum', namely firms that were established after the IMF's involvement and in the middle of the most important economic crisis of the country.

Table 2: The programs 'Green firm' and 'Green infrastructure' – Main economic sectors

Activities- Main economic sectors	Green Firm	Green Infrastructure
Food products	11.76	5.66
Textiles	1.96	
Wood and products of cork; articles of straw and plaiting materials	7.84	
Wearing apparel		1.89
Coke and refined petroleum products		3.77
Printing and reproduction of recorded media	5.88	
Chemicals and chemical products	13.73	
Rubber and plastic products	5.88	3.77
Other non-metallic mineral products	17.65	5.66
Basic metals	1.96	3.77
Fabricated metal products	15.69	
Machinery and equipment n.e.c.	5.88	
Manufacture of furniture	5.88	
Other manufacturing	1.96	
Electricity, gas, steam and air conditioning supply		1.89
Sewerage		1.89
Waste collection, treatment- disposal activities; materials recovery	1.96	54.72
Civil engineering		3.77
Wholesale trade, except of motor vehicles and motorcycles		9.43
Services to buildings and landscape activities		1.89
Other mining and quarrying		1.89
Sale, maintenance, repair of motorcycles and parts and accessories	1.96	

Source: Own elaboration of interview data and web research.

The parameter of the 'size of the firm '(based on the number of total employment) ended up in, more or less, expected results. Most firms are micro and small, thus firms employing up to 50 employees, with those of the 'Green Firm' program being smaller than those of the other program. Firms in the 'Green Infrastructure' program should be larger, because of their kind of investment they aim at.

However, this result may be problematic, as there was no data for the 26.42% (15 firms) of firms of this program. Exports are important in most cases, as they express the openness of a firm, its extrovert nature and its exposure on the international competition. The comparison between the two programs shows that the firms of the 'Green Firm' program are more open and extrovert, as the number of firms with exports is more than twice of the respective number of the 'Green Infrastructure' program. However, it has to be acknowledged that the 'Green Infrastructure' program concerns activities which are less exportable from their nature (e.g. waste management is less exportable than other non metallic mineral products).

Table 3: The programs 'Green firm' and 'Green infrastructure' – Main features

Program: Green Firm	**Program: Green Infrastructure**
Establishment (year) Before 1974: 15.69% After 1974- Before EMU: 72.55% After EMU- Olympic games: 3.92% After Olympic games- Before the memorandum: 1.96% After the memorandum: 3.92% No data: 2 firms- 1.96%	Establishment (year) Before 1974: 5.66% After 1974- Before EMU: 24.53% After EMU- Olympic games: 11.32 After Olympic games- Before the memorandum: 30.19% After the memorandum: 24.53% No data: 3 firms- 3.77%
Employment (number) Micro: 31.37% Small: 50.98% Medium (50- 100): 7.84% Medium (100- 250): 0 No data: 5 firms - 9.80%	Employment (number) Micro: 32.08% Small: 26.42% Medium (50- 100): 11.32% Medium (100- 250): 3.77% No data: 15 firms- 26.42%
Exports (%) and regions of exports 0-5: 3.92% (Europe) 5-10: 5,88% (Europe) 10-20: 7.84% (Europe, America, M. East) 20-50: 3.92% (Europe, Middle East) >50: 1.96% (Europe, Africa) No data: 39 firms- 76.47% Firm with exports but no recorded percentage: 6 firms- 15.38%	Exports (%) and regions of exports 0-5: 0 5-10: 1.89% (Europe) 10-20: 0 20-50: 1.89% >50: 7.55% (Europe, Middle East, Asia) No data: 88.68% Firm with exports but no recorded percentage: 1 firm-2.12%
Geography (regional distribution, %) Eastern Macedonia- Thrace: 11.76% Attica: 25.49% Northern Aegean: 0 Western Greece: 7.84% Western Macedonia: 3.92% Epirus: 3.92% Thessaly: 7.84% Ionian Islands: 0 Central Macedonia: 17.65% Crete: 3.92% Southern Aegean: 1.96% Peloponnesus : 7.84% Sterea Ellada : 7.94% **Concentration Index: 0.13**	Geography (regional distribution, %) Eastern Macedonia- Thrace: 11.32% Attica: 35.85% Northern Aegean: 1.89% Western Greece: 0 Western Macedonia: 3.77% Epirus: 3.77% Thessaly: 5.66% Ionian Islands: 0 Central Macedonia: 15.09% Crete: 3.77% Southern Aegean: 0 Peloponnesus : 7.55% Sterea Ellada : 11.32% **Concentration Index: 0.19**

Source: Own elaboration of interview data and web research.

In addition, this result may also be problematic, for the great majority of firms for both programs didn't provide a definite answer on the issue of exports based on the replies of the managers in the questionnaires.

Last but not least, there is the parameter of geography. The location of firms, classified at regional level is similar with the results of other studies for the Greek case, confirming this way the importance of first Attica (the region of Athens, the capital of Greece), second Central Macedonia (the region of Thessaloniki, the second in population municipality in Greece) and four other regions with similar shares, which in pairs formulate two single geographical units (Thessaly and Sterea Ellada formulate Central Greece, while Western Greece and Peloponnesus compose the main part of the continental southern Greece). However, the geographical pattern of the firms of the 'Green Firm' program is more dispersed, concerning more firms from different Greek regions.

5. Conclusions

The issue of entrepreneurship is central in the effort towards green growth. Given its importance, the concept of green entrepreneurship was emerged and developed. In this context, this paper attempted to link aspects of green policy to green results, aiming at the target of green growth in the future for the case of Greece, by studying and examining the response of Greek firms to the national call for boosting green entrepreneurship. The Greek policy on green entrepreneurship was expressed by the launch of three programmes, with the two of them already being completed and the third at the stage of evaluation of the submitted proposals. The two completed programs are the 'Green Firm' and the 'Green infrastructure' program. Totally, an amount of 60,000,000 m. euro could be provided to the Greek investors in the form of government funding- subsidies for this purpose. The 'Green Firm' program aimed at creating the necessary conditions for the integration of the environmental dimension in the operation of firms, by making interventions in their production chain, so that the area of the protection of the environment becomes a main field of the business activity. Accordingly, the program 'Green Infrastructure' aimed at creating the necessary conditions so as the area of the protection of the environment becomes a field of entrepreneurial activity.

This paper showed that the Greek entrepreneurs didn't respond sufficiently to this new reality of entrepreneurship, which compromises the desire for profitability and growth and the need for environmental protection, addressing the whole task as an opportunity and not as an obstacle neither a choice after pressure. Green entrepreneurship is one of main pylons of the European policy, which is now slowly taking hold in Greece, in compliance with the whole spectrum of Community- European policies as well as an awareness of the part of the political and entrepreneurial community to its potential. Perhaps it is still early for the Greeks entrepreneurs to engage in such actions or maybe a different approach may be needed for their activation. In any case, the challenge of Green entrepreneurship is the challenge of the immediate future, whose framework should now be established to offer a return in the future. This should be the target of those who decide and those who invest.

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Population, economic growth and regional environmental performance: A conditional directional distance function approach

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Abstract
We apply a conditional directional distance function estimator in order to evaluate the effect of population size and GDP per capita (GDPPC) on US regions' environmental performance levels. We apply our analysis to the US regions for the years 1998 and 2008. The overall results reveal that there are a lot of environmental inefficiencies among the US states. After performing a second stage nonparametric analysis the results reveal that regions' population size has a negative effect on their environmental frontier only for regions with lower GDPPC levels. For regions with higher GRDPC levels the effect of population is positive. Moreover, there is evidence that the relationship between regions' environmental performance with regions population and GDPC levels is nonlinear.

Keywords: Regional environmental performance; Directional distance function; Conditional measures; Nonparametric regression.

JEL classification: C6, R11, Q5.

1. Introduction

The pioneer work by Kuznets (1955) was the first study providing evidence that that income disparities first rise and then begin to fall during economic development stages. Following, Kuznets (1955) several studies have tried to establish a similar type relationship between economic growth (in per capita terms) and environmental degradation/quality. A vast amount of literature consists of papers using the environmental Kuznets approach (EKC) to model emissions and determinants of policy choices. In a country level, Selden and Song (1994) and Grossman & Kruger (1995) provided evidence of an inverted U-type (Environmental Kuznets Curve-EKC) relationship between economic activity and environmental quality. Since then this relationship between economic activity and environmental quality has found support from many other studies (among others Ekins, 1997; Stern et al. 1996; Stern, 1998; 2002; 2004; Antweiler *et al*., 2001; Bulte and van Soest, 2001; Dasgupta et al., 2002; Halkos, 2003).

For the U.S. Carson et al. (1997) estimated cross-sectional EKC models for the US states for seven types of air emissions using data for 1990. They found that all seven pollutants decrease with increasing per capita income. They also found strong evidence of heteroscedasticity with respect to the income–emissions relationship: lower-income states display much greater variability in per capita emission levels than higher-income

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states. Furthermore, List and Gallet (1999) estimated EKC models for U.S. states for sulfur dioxide and nitrogen oxides emissions using panel data for 1929 to 1994. There was a lot of variance in estimated curves for individual states but the average turning point was very high. Panel models found turning points at $9000 per capita income in 1987 Dollars for NOx and $21,000 for SO2. The averages of the individual state models are similar. These results appear to contradict each other. The reason is that List and Gallet use state fixed effects (they also included a time trend) in their panel model and so their results depend mostly on the within variation whereas Carson *et al*.'s results depend on the between variation. States like West Virginia are poor but have a heavy focus on polluting industries such as coal mining and electricity generation. It is, therefore, important to control for such state effects when estimating environmental efficiency. Industry structure and energy use are possible relevant control variables.

Aldy (2005) uses a 1960 to 1999 U.S. state-level CO_2 emissions data set to estimate pretrade (production-based) CO_2 EKCs and posttrade (consumption-based) CO_2 EKCs. He finds that consumption-based EKCs peak at significantly higher incomes than production-based EKCs, suggesting that emissions-intensive trade drives, at least in part, the income-emissions relationship. There is a lot of trade in fuels and electricity between states. Estimated EKCs appear to vary by state. Finally, he finds that cold winters, warm summers, and historic coal endowments are positively associated with states' CO_2 emissions[56]. Matisoff (2008) carried out an empirical analysis of the factors affecting the adoption of energy efficiency programs across U.S. states. He finds that the most significant variable is citizen ideology. A broad band from Florida to Idaho has not adopted any policies. The initial level of criteria air pollutants was significant in OLS regressions for the number of programs adopted and in probit models for the adoption of a renewable portfolio standard. CO2 intensity of the economy was significant with negative sign in some regressions depending on how other energy variables were modeled or included. Gas and coal production per capita, income, and the policies of neighboring states did not have significant effects.

By contrast Fredriksson and Millimet (2002) find that states are influenced by their neighbors—both contiguous and regional neighbors—and the effect operates within a five year window. Moreover, the response is asymmetric. States are "pulled" to higher levels of abatement costs by improvements in neighbors with regulations that are already relatively stringent. Improvements by states with relatively lax regulations have no effect on their neighbors' environmental policymaking. Perhaps the difference between the results of these two papers are explained by the lack of control variables that are positively spatially correlated across states. Heckman (2012) analyzes the impact of management quality, spending, problem severity, and political factors on states' control of NOx emissions. Again, there is a consistent yet modest impact of citizen ideology on NOx emissions. More liberal citizens and more spending seem to contribute to modestly lower NOx emissions and greater reductions in emissions under the Clean Air Act (CAA). Additionally, the author demonstrates the benefits of conducting comparative empirical analysis using different, but theoretically connected, outcome measures.

A modelling technique that can be adopted in order to overcome such problems and model the trade off between environmental quality and economic development is

[56] Recently Auffhammer and Steinhauser (2012) have focused on forecasting U.S. carbon emissions using state level data.

the use of distance functions in a nonparametric setting. Färe et al. (1989) was the first to model the trade off between environmental quality and economic development providing therefore a measurement framework for environmental technology in a production function context. Additionally the proposed model has treated pollutant as an output of the production process and by imposing strong and weak disposability on inputs and outputs developed environmental performance indicators. Batabyal and Nijkamp (2004) suggested the importance of regional environmental policy as being a tradeoff between economic development and environmental quality. Since then several studies tried to establish an EKC type relationship between economic growth and environmental performance (among others Zaim and Taskin, 2000a, 2000b, 2000c; Taskin and Zaim, 2001; Zaim 2004; Managi, 2006; Yörük and Zaim 2006; Halkos and Tzeremes, 2009) most in a country level. This kind of analysis normally involves the construction of environmental performances of the evaluated Decision Making Units (DMUs) and a second stage regression type analysis.

However, as has been demonstrated by Simar and Wilson (2007, 2011) several assumptions regarding the data generating process (most of the times unsupported by economic data) are needed in order for the researchers to perform second-stage regressions involving data envelopment analysis (hereafter DEA) efficiency scores. In addition most of the two-stage DEA studies assume that separability condition between the input–output space and the space of the exogenous factors holds. Therefore they assume that these factors (external/exogenous to the environmental production process) have no influence on the attainable set, affecting only the probability of being more or less efficient (Bădin et al., 2010, p.634). Finally, as reported by Daraio et al. (2010) the exogenous variables affect directly the shape of the distribution of the inefficiencies but also the production possibilities themselves.

Recently, Halkos and Tzeremes (2013a, 2013b) in the measurement context of environmental performance overcame those problems by applying the probabilistic characterization of directional distance functions firstly introduced by Simar and Vanhems, 2012. Halkos and Tzeremes (2013a, 2013b) by imposing the weak disposability assumption on the outputs developed a conditional directional distance function estimator modelling for the first time the environmental performance economic growth relationship under constant and variable returns to scale. In this paper we extent the estimator by Halkos and Tzeremes (2013a) in a multivariate case measuring therefore the effect both of GDP per capita and population levels on U.S. regions' environmental performance. The paper is organised as follows: section two presents the data and the methodology adopted whereas section three presents the results obtained. The final section concludes the paper.

2. Data and Methodology

2.1 Description of variables

Following several other studies (Färe et al., 1989; Zaim and Taskin 2000a, 2000b, 2000c; Taskim and Zaim 2001; Färe and Grosskopf, 2004; Zaim 2004; Managi 2006; Yörük and Zaim 2006;) in our methodological setting we use a set of inputs and a set of bad and good outputs in order to define US regions' environmental production process. More analytically our data are referring to the 50 states of U.S.A. for the period

1998 and 2008[57]. The set of inputs used are capital stock (in millions of chained 2000 Dollars), energy use (in trillions of BTUs) and total state level employment. Furthermore, the good output is the real state GDP (in millions in 2005 Dollars) and the bad outputs are carbon monoxide (CO), mono-nitrogen oxides (NOx) and sulphur dioxide emissions (SO_2) measured in thousands of short tons. For the external/ environmental variables we have used states population levels (obtained from ratio of total and per capita GDP) and GDP per capita levels in 2005 constant Dollars.

The data used have been obtained from several sources. More analytically, states' total employment, real GDP and GDP per capita have been obtained from Bureau of Economic Analysis[58]. Total primary energy variable has been obtained from State Energy Data System (SEDS) provided from U.S. Energy Information Administration[59]. Moreover the air pollutants have been obtained from U.S. Environmental Protection Agency[60]. Finally, states' capital stock levels are estimates and have been obtained from Garofalo and Yamarik (2002) and Yamarik (2013). Table 1 below provides the descriptive statistics of the variables used in our analysis.

Table 1: Descriptive statistics of the variables

Year 1998	**Total Employment**	**Energy**	**Capital Stock**	**GDP**	**CO**	**NOx**	**SO_2**	**GDP per capita**	**Population**
Mean	3155576.000	1895624.840	190170.385	204406.660	1787.040	488.660	392.700	36133.180	5508867.114
Std	3346326.417	2109708.437	232276.828	236415.496	1539.858	404.319	410.440	6704.640	6043365.845
Min	313121.000	136346.000	18071.985	18086.000	216.000	35.000	12.000	25806.000	491653.744
Max	18370580.000	12468523.000	1210298.475	1270101.000	8072.000	2140.000	1921.000	56896.000	33029958.651
Year 2008	**Total Employment**	**Energy**	**Capital Stock**	**GDP**	**CO**	**NOx**	**SO_2**	**GDP per capita**	**Population**
Mean	3576691.200	1980384.060	235690.494	258570.420	1644.136	343.685	207.037	41897.420	6034151.438
Std	3837979.162	2033970.296	302948.278	313039.735	1715.051	295.745	230.953	7731.182	6686673.098
Min	399767.000	148943.000	21045.387	22772.000	146.482	21.427	4.157	28454.000	544912.884
Max	20706409.000	11513729.000	1562427.136	1756115.000	10513.779	1613.530	990.349	61460.000	36389378.147

2.2 Directional distance functions

In an environmental production process (Färe et al., 1989, 2004; Chung et al., 1997; Tyteca, 1996; 1997; Taskin and Zaim, 2001; Zofio and Prieto, 2001; Zaim, 2004; Picazo-Tadeo et al., 2005; Managi, 2006; Yörük and Zaim, 2006; Picazo-Tadeo and García-Reche, 2007)let the input vector denoted by $x \in \Re_+^N$ be able to produce both a set of undesirable $u \in \Re_+^J$ and desirable $v \in \Re_+^M$ outputs. Then following Shephard (1970) and Färe and Primont (1995) the environmental technology can be defined following several assumptions. More analytically, we assume that the output sets are closed and bounded and that inputs are freely disposal. In addition the environmental output set $P(x)$ can only be defined if:

[57]These are: Alabama, Alaska, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, Florida, Georgia, Hawaii, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, Wisconsin and Wyoming.

[58]The data can be downloaded from: http://www.bea.gov/regional/.

[59]The data can be downloaded from: http://www.eia.gov/beta/state/seds/seds-data-complete.cfm?sid=US.

[60]The data can be downloaded from: http://www.epa.gov/ttn/chief/index.html.

1. $(v,u)\in P(x)$ and $0\le\theta\le1$ then $(\theta v,\theta u)\in P(x)$ (i.e. the outputs are weakly disposable) and
2. $(v,u)\in P(x)$, $u=0$ implies that $v=0$ (i.e. the null jointness assumption of good and bad outputs).

The assumption of weak disposability indicates that the reduction of bad outputs is costly and therefore it can be obtained only by a simultaneously reduction of good outputs. Moreover the null jointness assumption suggests that the good outputs and bad outputs are null-joint. This in turn suggests that the bad outputs are byproducts of the production process when producing good outputs.

Based on the initial works by Luenberger (1992, 1994) and those by Chambers et al. (1996, 1998) the directional distance function or the Luenberger's benefit function has been very popular among the analysts. The flexibility characterizing the directional distance function (DDF) and the benefit function found increased popularity among the scholars in different areas of research[61]. Based on weak disposability assumption[62] for modelling undesirable outputs, a vast amount of research has been produced based on directional distance functions (among others Chung et al., 1997; Kuosmanen, 2005; Färe et al., 2006, 2007, 2010; Färe and Grosskopf, 2009; Kuosmanen and Podinovski, 2009). According to the relative literature the environmental technology can be formalized via the DDF in a nonparametric setting with the use of data envelopment analysis (DEA) estimators[63]. Following, several other studies (among others Chung et al., 1997; Macpherson et al. 2010; Picazo-Tadeo et al., 2005, 2012) we apply DDF approach in order to measure regions' environmental efficiency levels. More specifically we apply a direction vector $g=(g_v,-g_u)$ in order to be able to reduce bad and expand good outputs. As a result the environmental efficiency score for a region k'(let $k=1,...,K$ be the regions under investigation) can be obtained from:

$$D\left(x^{k'},v^{k'},u^{k'};g_v,g_u\right)=\max\beta$$
$$s.t.\left(v^{k'}+\beta g_v,u^{k'}-\beta g_u\right)\in P(x) \qquad (1), \text{ or}$$

as the solution to the following linear problem:

$$\begin{aligned} &D\left(x^{k'},v^{k'},u^{k'};g_v,g_u\right)=\max\beta\\ &s.t. \quad \sum_{k=1}^{K}\omega_k v_{km}\ge v_{k'm}+\beta g_{vm}, m=1,...,M,\\ &\qquad \sum_{k=1}^{K}\omega_k u_{kj}=u_{k'j}-\beta g_{uj}, j=1,...,J,\\ &\qquad \sum_{k=1}^{K}\omega_k x_{kn}\le x_{k'n}\\ &\qquad \omega_k\ge0, k=1,...,K. \end{aligned} \qquad (2).$$

[61]Just recently Zelenyuk (2013) has provided the scale elasticity measures based on directional distance function for multi-output– multi-input technologies alongside with their properties and the equivalence with the input oriented and output oriented scale elasticity measures.

[62]For the economic interpretation of weak disposability using the dual formulations see Kuosmanen and Matin (2011).

[63]For applications, advantages and disadvantages of DEA estimators see the studies by Pollitt (1996), Resende (2000), Krüger (2003) and Cullmann et al. (2011).

$\omega_k, k = 1,...,K$ indicate the intensity variables which are not negative and imply constant return to scale[64].

Normally as in many DDF studies environmental efficiency will be indicated when $D\left(x^{k'}, v^{k'}, u^{k'}; g_v, g_u\right) = 0$ and environmental inefficiency when $D\left(x^{k'}, v^{k'}, u^{k'}; g_v, g_u\right) > 0$. However for the needs of our analysis we transform the obtained inefficiencies to efficiencies following the transformation proposed Chung et al. (1997, p.232, equation 2.9). As a result an environmental efficient region will be indicated with environmental efficiency scores equal to 1 and environmental inefficient regions will be indicated with environmental efficiency scores less than 1.

2.3 Conditional directional distance functions

According to Mastromarco and Simar (2014) the majority of nonparametric and parametric frontier studies impose some restrictive and unverifiable prior assumptions (Simar and Wilson, 2007, 2011) in order to model the effect of the environmental factors[65] on the production process. By applying one-stage or two-stage approaches most of these studies are trying to capture the heterogeneity caused by the environmental factors on the obtained efficiency scores by imposing several (most of time) unrealistic assumptions. One of the main problem with the majority of the two-stage DEA studies is the assumption of the 'separability condition' between the input–output space and the space of the environmental factors. Under this condition those studies are wrongly assume that the environmental factors have no influence on the attainable set, affecting only the probability of a decision making unit (DMU) to be more or less efficient (Bădin et al., 2010, p.634).

This problem can be tackled with the application of conditional efficiency measures[66] based on the probabilistic formulation of the production process introduced by Daraio and Simar (2005, 2006, 2007)[67]. Lately Simar and Vanhems (2012) have introduced the probabilistic characterization of the directional distance functions for full and robust measures. The first study applied the probabilistic characterization of the DDFs to the environmental problem was conducted by Halkos and Tzeremes (2013a) examining the influence of economic growth on UK regions' environmental performance. The pre-mentioned study applies conditional DDFs for the univariate case of an environmental factor affecting environmental production process and under the assumption of constant returns to scale[68]. However, the proposed study extends the analysis in a multivariate case examining how regions' GDP per capita and population levels affect their environmental performance in a DDF framework.

[64]According to Picazo-Tadeo et al. (2012, p.802) from an ecological perspective, economic activity is commonly characterised by constant returns to scale. Still if a researcher wants to impose variables returns to scale (VRS) in this model, it is suggested to take into consideration the remarks raised by Kuosmanen (2005), Färe and Grosskopf (2009), Kuosmanen and Podinovski (2009) and Podinovski and Kuosmanen (2011).

[65]The environmental factors are called all the exogenous factors which are not under the direct control of the decision maker and hence can influence the evaluated production process.

[66] For the theoretical background and the asymptotic properties of nonparametric conditional efficiency measures see Jeong et al. (2010).

[67]Daraio and Simar (2005, 2006, 2007) have extended the probabilistic characterization of the production process based on the work by by Cazals et al. (2002).

[68]For a conditional DDF measuring environmental performance under the assumption of variable returns to scale see Halkos and Tzeremes (2013b).

Following Daraio and Simar (2005) let the joint probability measure of $\left(X,V,U\right)$ and the joint probability function of $H_{X,V,U}\left(.,.\right)$ be defined as:

$$H_{X,V,U}\left(x,v,u\right)=\text{Prob}\left(X\leq x,V\geq v,U\geq u\right) \quad (3).$$

In addition the following decomposition can be obtained as:

$$H_{X,V,U}\left(x,v,u\right)=\text{Prob}\left(V\geq v,U\geq u\middle|X\leq x\right)\text{Prob}\left(X\leq x\right)=S_{V,U|X}\left(v,u\middle|x\right)F_X\left(x\right) \quad (4),$$

where $F_X\left(x\right)=\text{Prob}\left(X\leq x\right)$ and $S_{V,U|X}\left(v,u\middle|x\right)=\text{Prob}\left(V\geq v,U\geq u\middle|X\leq x\right)$.

Furthermore, let $Z\in R^r$ denote the exogenous-environmental factors influencing regions' environmental production process (in our case these are regions' GDP per capita-GDPPC and population levels-POP). Then equation (3) becomes:

$$H_{X,V,U|Z}\left(x,v,u\middle|z\right)=\text{Prob}\left(X\leq x,V\geq v,U\geq u\middle|Z=z\right) \quad (5),$$

which completely characterizes regions' environmental production process. According to Daraio and Simar (2005, 2006, 2007) the following decomposition can be derived:

$$\begin{aligned}H_{X,V,U|Z}\left(x,v,u\middle|z\right)&=\text{Prob}\left(V\geq v,U\geq u\middle|X\leq x,Z=z\right)\text{Prob}\left(X\leq x\middle|z\right)\\&=S_{V,U|X,Z}\left(v,u\middle|x,z\right)F_{X|Z}\left(x\middle|z\right)\end{aligned} \quad (6).$$

The estimator of the conditional survival function introduced above can be obtained from:

$$\hat{S}_{V,U|X,Z}\left(v,u\middle|x,z\right)=\frac{\sum_{i=1}^{n}I\left(V_i\geq v,U_i\geq u,X_i\leq x\right)K\left(\left(Z_i-z\right)/h\right)}{\sum_{i=1}^{n}I\left(X_i\leq x\right)K\left(\left(Z_i-z\right)/h\right)} \quad (7),$$

where $K(.)$ is a kernel function defined on a compact support (Epanechnikov in our case) and h is the appropriate bandwidth calculated following Bădin et al. (2010)[69]. However when $r>1$ (as in our case $r=2$) , $Z=\left(Z^1,...,Z^r\right)$ and is multivariate, we follow Daraio and Simar (2014) and we use a product kernel with a vector of bandwidths $h=\left(h_1,...,h_r\right)$ and $K\left(\left(Z_i-z\right)/h\right)$ is the shortcut for $\prod_{l=1}^{r}K\left(\left(Z_i^l-z^l\right)/h_l\right)$

Recently Simar and Vanhems (2012) developed the probabilistic characterization of directional distance function taking the general form of:

$$D\left(x,y;g_x,g_y\right)=\sup\left\{\beta>0\middle|H_{XY}\left(x-\beta g_x,y+\beta g_y\right)>0\right\} \quad (8)$$

and the conditional directional distance function of $\left(x,y\right)$ conditional on $Z=z$ can then be defined as:

$$D\left(x,y;g_x,g_y\middle|z\right)=\sup\left\{\beta>0\middle|H_{XY|Z}\left(x-\beta g_x,y+\beta g_y\middle|Z=z\right)>0\right\} \quad (9).$$

Following Halkos and Tzeremes (2013a) the probabilistic form of Färe and Grosskopf's (2004) model measuring environmental efficiency can be presented as:

$$D\left(x^{k'},v^{k'},u^{k'};g_v,g_u\right)=\sup\left\{\beta>0\middle|H_{X,V,U}\left(x^{k'},v^{k'}+\beta g_v,u^{k'}-\beta g_u\right)>0\right\} \quad (10).$$

Then the conditional form of the model will take the form of:

$$D\left(x^{k'},v^{k'},u^{k'};g_v,g_u\middle|z\right)=\sup\left\{\beta>0\middle|H_{X,V,U|Z}\left(x^{k'},v^{k'}+\beta g_v,u^{k'}-\beta g_u\middle|Z=z\right)>0\right\} \quad (11).$$

[69] The calculation of bandwidth by Bădin et al. (2010) is based on the Least Squares Cross Validation (LSCV) criterion introduced by Hall et al. (2004) and Li and Racine (2007).

Finally, the DEA program for the environmental efficiency score for a region k' when using the conditional output oriented directional distance function can be calculated as:

$$D\left(x^{k'}, v^{k'}, u^{k'}; g_v, g_u \middle| z\right) = \max \beta$$

$$\begin{aligned} s.t. \quad & \sum_{\substack{k=1,\dots,K| \\ |Z_k - z| \le h}} \omega_k v_{km} \ge v_{k'm} + \beta g_{vm}, m = 1,\dots,M, \\ & \sum_{\substack{k=1,\dots,K| \\ |Z_k - z| \le h}} \omega_k u_{kj} = u_{k'j} - \beta g_{uj}, j = 1,\dots,J, \\ & \sum_{\substack{k=1,\dots,K| \\ |Z_k - z| \le h}} \omega_k x_{kn} \le x_{k'n} \\ & \omega_k \ge 0, k = 1,\dots,K \text{ such that } |Z_k - z| \le h. \end{aligned} \tag{12}$$

As shown previously efficient regions will be indicated when $D\left(x^{k'}, v^{k'}, u^{k'}; g_v, g_u \middle| z\right) = 0$ and inefficient regions will respectively be specified by values of $D\left(x^{k'}, v^{k'}, u^{k'}; g_v, g_u \middle| z\right) > 0$. Again as explained previously the results obtained from the conditional DDFs will be transformed to efficiency measures following the transformation provided by Chung et al. (1997). Therefore the environmental efficient regions under the effect of their GDPPC and population levels will be indicated with 1, whereas the inefficient regions will be indicated with conditional environmental efficiency scores less than 1.

As has been noted by Mastromarco and Simar (2014, p.6) the only difference between the two estimators presented in (2) and (12), is that the estimator presented in (12) describes the local directional distance estimates which are the product of the localizing procedure estimating conditional directional distance function which are determined by the data points in a neighborhood of z. As a result the proposed estimator is able to account directly the effects of regions' GDPPC and population levels on their environmental performance. Therefore the environmental efficiency estimates obtained are determined by the inputs, the good, the bad outputs and both the two environmental factors (regions' GRPPC and population levels). Finally, we are not imposing in our analysis the restrictive separability assumption between regions' environmental performance and their GDPPC and population levels (Simar and Wilson 2007, 2011).

2.4 Determining the effect of the regions' economic growth and population levels

Finally, following Bădin et al. (2012) we can identify the effects of the environmental variables (GDPPC and population levels) on regions environmental frontier (frontier shift). This can be obtained if we examine the ratios of conditional to unconditional regional environmental efficiency measures:

$$\hat{Q} = \frac{\hat{D}\left(x^{k'}, v^{k'}, u^{k'}; g_v, g_u \middle| z\right)}{\hat{D}\left(x^{k'}, v^{k'}, u^{k'}; g_v, g_u\right)} \tag{13}$$

Following Bădin et al. (2012) we can look these ratios as a function of GDPPC and population level and therefore we can investigate the effect regional economic growth and population level on the potential shift of US regions' environmental frontier.

Therefore we can investigate if for a particular regional economic growth and population level there is a shift on regions' environmental frontier. For this reason we are using the local linear estimator (Fan 1992, 1993) in order to regress regions' GDPPC and population levels on the ratios of the conditional to unconditional environmental efficiency estimates. For our case (output oriented DDFs) an increasing nonparametric regression line will indicate a favorable effect of regions' economic growth and population levels on their environmental efficient frontier (i.e. the conditional frontier moves up to the unconditional one). In the opposite way a decreasing nonparametric line will indicate an unfavorable effect.

3. Empirical results

Table 2 presents the analytical results of U.S. regions' environmental performance (REE) for the two examined periods[70]. For the original estimates and for the year 1998 twelve states are reported to be environmental efficient (i.e. REE score equals to 1)[71]. For the year 2008 nineteen states are reported to be environmental efficient. Over the two years Table 2 indicates that twenty three states have increased their environmental performance, twenty one have decreased them and seven have remained unchanged. In fact these seven states have reported to be environmental efficient regions for both the examined years. These regions are Alaska, California, Delaware, Montana, South Dakota, Vermont, and Wyoming. On average terms (i.e. the average REE for the two periods) the seventeen regions with the highest performance (with average REE score ≥ 0.9) are: Alaska, California, Delaware, Hawaii, Maryland, Mississippi, Montana, Nebraska, New Mexico, North Carolina, North Dakota, Rhode Island, South Dakota, Utah, Vermont, Virginia and Wyoming. Whereas the eighteen regions with the lowest performances (with average REE score < 0.8) are: Alabama, Arkansas, Colorado, Georgia, Illinois, Indiana, Kentucky, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New York, Oklahoma, Tennessee, Texas, West Virginia and Wisconsin. Finally, the descriptive statistics in Table 2 reveals that on average terms the REE levels have dropped significantly when we account for the effect of regions' GDPPC and population levels.

Furthermore, Figure 1 presents the kernel density functions of the conditional and unconditional REE scores. For the calculation of the density estimates we have used for bandwidth selection the "normal reference rule-of-thumb" approach (Silverman, 1986) and a second order Gaussian kernel. Sub-figure 1a illustrates the distribution of the unconditional and conditional environmental efficiency estimates for 1998, whereas the sub-figure 1b for the year 2008. AS can be realised for both years the distribution of the conditional estimates is platykurtic. As a result regions' environmental efficiency estimates are highly dispersed and their distribution is less clustered around the mean than in a leptokurtic distribution. For the case of unconditional estimates a twin peak distribution is revealed both for 1998 and 2008. More specifically a bimodal distribution is revealed having one group of regions with REE levels of 0.8 and another of 1. Moreover for the year 2008 the twin-peaked distribution is reported for 0.7 and 1 REE

[70]Table 2 presents also the conditional estimates REE|z for 1998 and 2008. However since these efficiency estimates include the effect of regions' GDPPC and population level is not meaningful to be used for ranking purposes (Mastromarco and Simar, 2014).

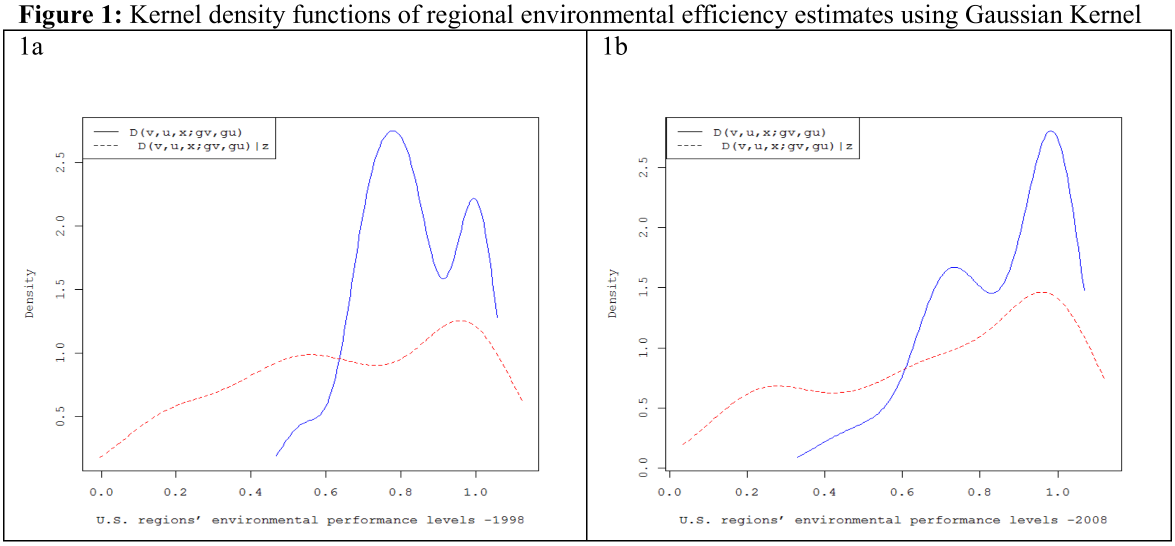
[71]As has been analyzed previously regions' environmental performance reflects the ability of a region to maximize the good output and simultaneously minimize the bad outputs given their input quantities.

levels. Clearly this result complements the analytical findings presented previously indicating to dominate groups of regions with high and low REE levels.

Table 2: Analytical results of regions' environmental efficiency estimates

States	REE_{1998}	REE_{2008}	$REE\|z_{,1998}$	$REE\|z_{,2008}$	States	REE_{1998}	REE_{2008}	$REE\|z_{,1998}$	$REE\|z_{,2008}$
Alabama	0.834	0.730	0.652	0.595	*New Hampshire*	1.000	0.542	1.000	1.000
Alaska	1.000	1.000	1.000	1.000	*New Jersey*	0.757	1.000	0.581	1.000
Arizona	0.795	0.903	0.128	0.858	*New Mexico*	0.996	1.000	0.936	1.000
Arkansas	0.804	0.783	0.274	0.578	*New York*	0.523	0.746	0.467	0.195
California	1.000	1.000	0.526	1.000	*North Carolina*	0.801	1.000	0.922	1.000
Colorado	0.708	0.680	0.376	0.926	*North Dakota*	1.000	0.929	1.000	0.916
Connecticut	0.781	0.896	0.655	0.707	*Ohio*	1.000	0.655	1.000	0.717
Delaware	1.000	1.000	0.529	0.330	*Oklahoma*	0.731	0.464	0.527	0.250
Florida	0.793	0.877	0.137	0.218	*Oregon*	0.689	1.000	0.561	0.737
Georgia	0.703	0.643	0.880	0.693	*Pennsylvania*	0.731	1.000	0.185	1.000
Hawaii	0.875	1.000	0.187	1.000	*Rhode Island*	0.861	1.000	0.293	1.000
Idaho	0.708	0.978	0.454	0.717	*South Carolina*	0.835	0.773	0.812	0.499
Illinois	0.669	0.691	0.313	0.674	*South Dakota*	1.000	1.000	0.826	0.845
Indiana	0.796	0.684	0.478	1.000	*Tennessee*	0.828	0.726	0.745	0.305
Iowa	0.794	0.820	0.402	0.162	*Texas*	0.534	0.397	0.686	0.197
Kansas	1.000	0.748	1.000	0.692	*Utah*	0.899	1.000	0.738	1.000
Kentucky	0.853	0.687	1.000	0.499	*Vermont*	1.000	1.000	1.000	1.000
Louisiana	0.992	0.806	1.000	0.621	*Virginia*	1.000	0.926	1.000	0.920
Maine	0.794	0.856	0.195	0.441	*Washington*	0.745	1.000	0.442	1.000
Maryland	0.809	1.000	1.000	0.155	*West Virginia*	0.775	0.676	0.856	0.659
Massachusetts	0.560	1.000	1.000	0.802	*Wisconsin*	0.711	0.661	0.473	0.502
Michigan	0.663	0.540	0.118	0.842	*Wyoming*	1.000	1.000	1.000	1.000
Minnesota	0.722	0.776	0.653	0.268	*Mean*	*0.8246*	*0.8433*	*0.6604*	*0.7029*
Mississippi	0.877	0.924	0.662	0.980	*Std*	*0.1342*	*0.1669*	*0.2937*	*0.2950*
Missouri	0.724	0.703	0.612	0.271	*Min*	*0.5230*	*0.3970*	*0.1180*	*0.1550*
Montana	1.000	1.000	1.000	1.000	*Max*	*1.0000*	*1.0000*	*1.0000*	*1.0000*
Nebraska	0.851	1.000	0.819	1.000					
Nevada	0.710	0.944	0.922	0.372					

Figure 1: Kernel density functions of regional environmental efficiency estimates using Gaussian Kernel



Following Bădin et al. (2012) we can investigate the potential effects of the conditioning variables (GDPPC and population levels in our case) on the boundary (shift of the frontier). As analyzed previously this can be obtained by considering the ratios of conditional to unconditional directional distance measures $\left(\hat{Q}\right)$. When the ratios increase with the conditioning variables indicate a favorable effect and unfavorable in the opposite case. Figure 2 illustrates the combined effect of regions' GDPPC and population levels on regions' environmental performance in 3-dimentional graphs. More analytically sub-figure 2a presents the combined effect of the conditioning variables for 1998. As can be observed the regions with higher population levels and higher GDPPC levels affect positively REE levels indicating a swift of the frontier. However, higher populated regions but with lower GDPPC levels affect negatively REE levels. There is evidence that higher GDPPC levels accelerate environmental technology change (swift of the frontier). Similar results are also revealed for 2008 (sub-figure 2b), indicating that there is a negative effect of lower GDPPC and higher population levels and a positive effect of higher GDPPC and higher population levels. Finally, subfigure 2c provides the analysis when we are considering into our analysis the whole sample both for 1998 and 2008. The results reveal the existence of an inverted 'U' shape for the REE–GDPPC relationship, whereas for the REE–population relationship the results reveal a 'U' shape. This finding suggests that for less populated regions GDPPC levels affect positively regions' frontier up to a certain level, which after that the effect becomes negative. Moreover, for higher populated regions the effect of GDPPC is positive only for high GDPPC levels. For lower GDPPC levels the effect is negative.

Figure 2: The effect of GDPPC and population on regions' environmental performance levels.

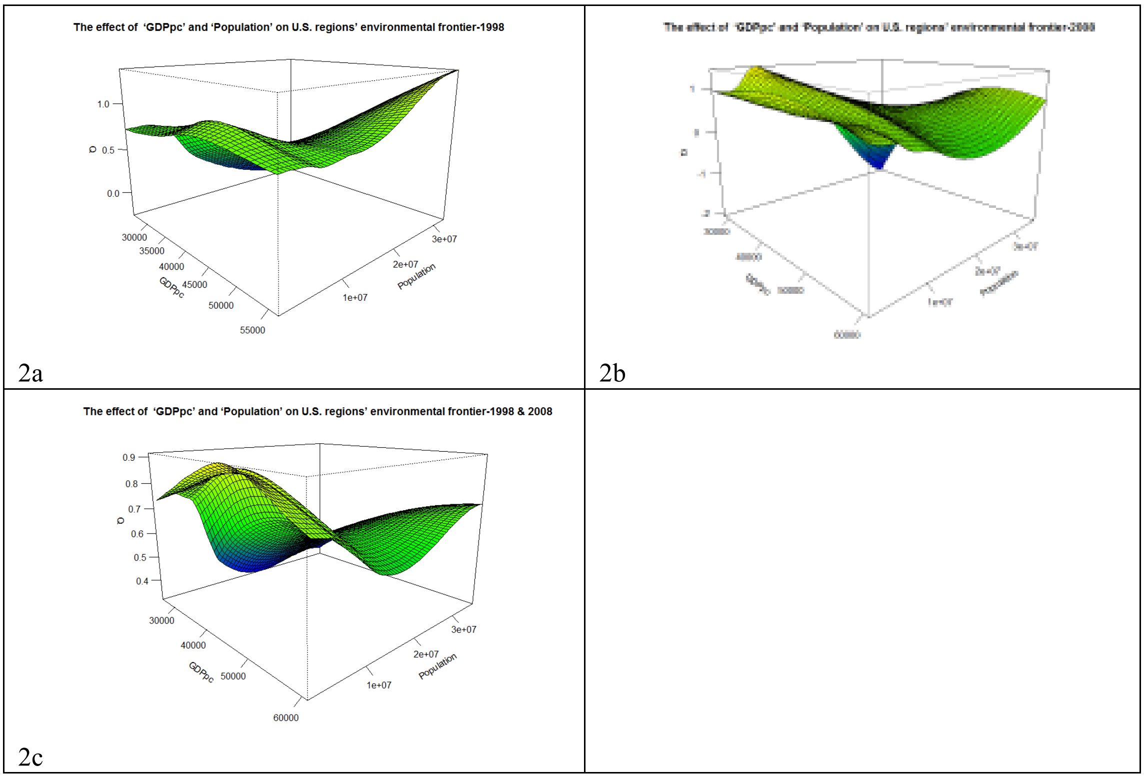
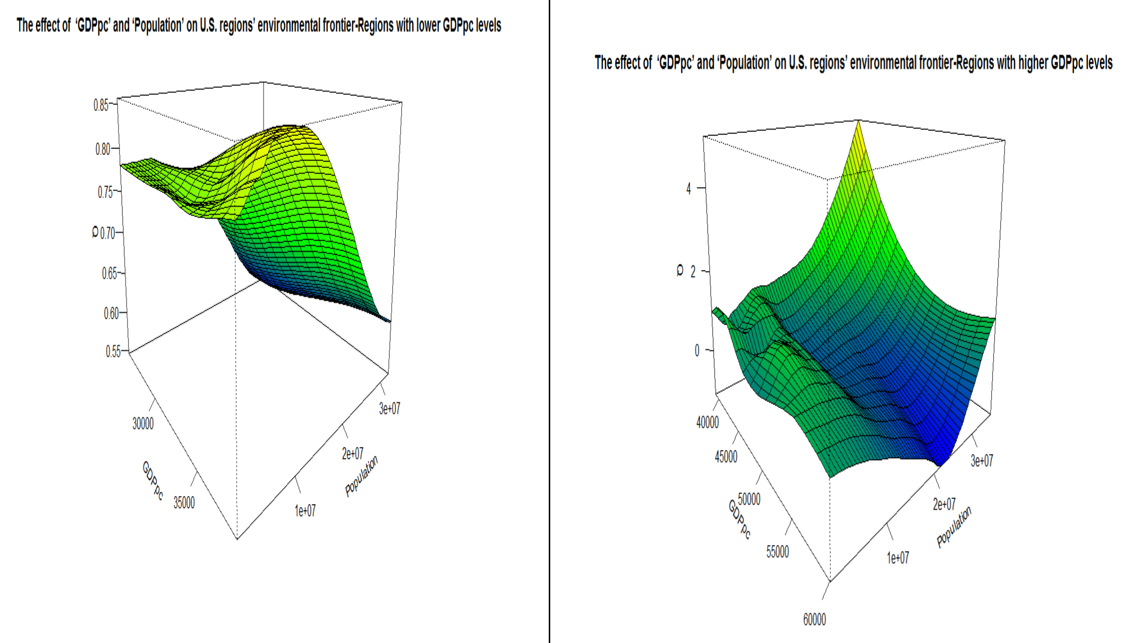


Figure 3 further analyses the effect of GDPPC and population on regions' REE levels by separating our analysis into two sub-samples (for both years combined). The first sub-sample investigates the effect of the conditioning variables on regions' environmental performance for regions with GDPPC levels up to 40000 Dollars (sub-figure 3a) and the other sub-sample investigates the effect on regions' environmental performance for regions with GDPPC levels above 40000 Dollars. Sub-figure 3a indicates a positive effect of GDPPC on regions' environmental frontier only between 35000 to 40000 Dollars. Moreover, the 3-dimensional graph suggests that highly populated regions have a negative effect on their environmental frontier. As a result the findings suggest that regions' with lower GDPPC and high population levels tend to have lower environmental performances. Moreover, sub-figure 3b investigates the effect of the conditioning variables for regions with higher GDPPC levels. The results reveal that the effect of GDPPC on regions' environmental frontier is positive especially for values between 45000 to 60000 Dollars. However for this GDPPC values the effect of population reveals a 'U' shape form indicating that the effect is negative for lower populated regions (but with higher GDPPC levels) and positive for higher populated regions. Finally, the results reveal that higher population levels have a positive effect on regions' environmental frontier only for those regions with GDPPC levels between 40000 to 45000 Dollars.

Figure 3: The effect of GDPPC and population on regions' environmental performance levels (for regions with higher and lower GDPPC levels)

3a

3b



4. Conclusions

This paper examines the effect of regions' GDPPC and population levels on their environmental performance levels. By following the relative literature on the probabilistic characterization of directional distance function (Simar and Vanhems, 2012) we extend for the multivariate case the environmental performance estimator proposed by Halkos and Tzeremes (2013a) applying weak disposability of outputs on the conditional directional distance functions. More analytically we investigate for the years 1998-2008 the effect of GDPPC and population on U.S. regions environmental performance. The results reveal an inverted 'U' shape relationship between GDPPC levels and regions' environmental frontier. Our results complement the findings of Halkos and Tzeremes (2013a, 2013b) investigating the effect of GDPPC for the U.K. and U.S. regions.

Moreover there is evident that highly population levels have a positive effect on regions' environmental frontier but only for regions' with higher GDPPC levels. In addition higher population levels affect negatively regions' environmental frontier for those regions' with lower GDPPC levels. Finally, we can conclude that population does not have always a negative effect on regions' environmental performance but also it depends on regions' GDPPC levels. In addition higher GDPPC levels do not always result on higher REE levels.

Acknowledgements
We would like to thank Professor David I. Stern for the provision of data and for the useful comments and suggestions made to our manuscript. Any remaining errors are solely the authors' responsibility.

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Η Αστικοποίηση στην Ανατολική Μεσόγειο και οι επιδράσεις της στην ατμοσφαιρική ρύπανση, το κλίμα και το οικοσύστημα: Η περίπτωση του Λεκανοπεδίου Αττικής

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Περίληψη
Η κλιματική αλλαγή αποτελεί την μεγαλύτερη περιβαλλοντική οικονομική και κοινωνική κρίση στην ιστορία της ανθρωπότητας. Το πρόβλημα επιτείνεται με την μείωση των αποθεμάτων τροφών, την όξυνση των ωκεανών, τις εκπομπές διοξειδίου του άνθρακα, την αποψίλωση των δασών και το φαινόμενο του θερμοκηπίου. Το πρόβλημα είναι μεγαλύτερο στην Μεσόγειο που αποτελεί κλειστό οικοσύστημα. Η παρούσα έρευνα μελετά αδρά τους ατμοσφαιρικούς ρύπους από την Αθήνα, το Κάιρο και την Κωνσταντινούπολη που επηρεάζουν το κλίμα της ανατολικής Μεσογείου. Εστιάζει στις κλιματικές αλλαγές που προκαλεί η αυξημένη δόμηση των πόλεων και η δημιουργία αστικών νησίδων στις μεγαλουπόλεις της Μεσογείου με επικέντρωση στην Αθήνα και στο πως η γεωμορφολογία της περιοχής επηρεάζει την ατμοσφαιρική ρύπανση. Η έλλειψη χώρων πρασίνου και η σημαντική μείωση τους με σκοπό να αυξηθεί ο δομικός ιστός έχουν αρνητικές συνέπειες τόσο στο περιβάλλον, όσο και στην ανθρωπινή υγεία. Ερευνώνται τα αίτια και οι επιπτώσεις της ατμοσφαιρικής ρύπανσης τόσο στο μικροκλίμα, τις θερμοκρασίες, την παραγωγή, όσο και στην υγεία. Οι εκπομπές των αέριων ρύπων έχουν αυξηθεί τη τελευταία δεκαετία με εμφανή αποτελέσματα στα επίπεδα της θερμοκρασίας των πόλεων τόσο στην Μεσόγειο όσο και παγκοσμίως αλλά με εμφανείς πλέον επιπτώσεις στην υγεία του ατόμου. Ερευνώνται τελευταία δεδομένα και προτάσεις για την αναχαίτιση του προβλήματος με πεδίο εφαρμογής το Λεκανοπέδιο Αττικής.

Λέξεις Κλειδιά -Q54: Κλιματική αλλαγή; αστική νησίδα; χώροι πρασίνου; υγεία

1. Εισαγωγή

Ο πλανήτης έτσι όπως τον γνωρίζει ο άνθρωπος εδώ και 150.000 χρόνια αλλάζει μη αναστρέψιμα, εξαιτίας των ανθρώπινων δραστηριοτήτων, με τόσο έντονες αλλαγές ώστε να θεωρείται πλέον ότι έχουμε εισέλθει σε μια νέα γεωλογική εποχή την «Ανθρωπόκαινο». Όσο τα αέρια του θερμοκηπίου συσσωρεύονται, η ατμόσφαιρα γίνεται πιο αδιαφανής, και η εξερχόμενη ακτινοβολούμενη θερμότητα, παγιδεύεται στα χαμηλότερα στρώματα της ατμόσφαιρας με αποτέλεσμα η επιφάνεια της γης να θερμαίνεται. Οι εκπομπές του διοξειδίου του άνθρακα, που προέρχονται από τις βιομηχανίες και την καύση ορυκτών καυσίμων και την παραγωγή τσιμέντου, αυξάνονται στο 37%. Κατά την περίοδο 2000-2007 οι εκπομπές διοξειδίου του άνθρακα, αυξήθηκαν κατά 27% στην Αμερική, ενώ στην Κίνα κατά 150%. Η αποψίλωση των δασών και δη των τροπικών που φτάνει τα 130 εκατομμύρια στρέμματα ετησίως προσθέτει 6,5 δισεκατομμύρια τόνους διοξειδίου στην ατμόσφαιρα. Οι φυσικές «καταβόθρες της γης – ωκεανοί και βιολογικά συστήματα- έπαψαν πλέον να μπορούν να απορροφήσουν τα απόβλητα.

Η κλιματική αλλαγή τείνει να γίνει μη αναστρέψιμη. Η απώλεια πάγων της Ανταρτικής θα επιτρέψει μεγαλύτερη θέρμανση των αρκτικών ωκεανών και θα θέσει σε κίνδυνο το στρώμα πάγου που καλύπτει τη Γροιλανδία. Επιπροσθέτως, το λιώσιμο των πάγων της τούνδρας απελευθερώνει μεγάλες ποσότητες διοξειδίου του άνθρακα και μεθανίου. Η Ευρώπη δεσμεύτηκε να μειώσει τις εκπομπές της κατά 20% μέχρι το 2020 σε σχέση με το 1990 αλλά και 30% αν οι άλλες βιομηχανικές χώρες με την σειρά τους δεσμευτούν από μια ισχυρή διεθνή συμφωνία.

Τα τελευταία 100 χρόνια η αύξηση της θερμοκρασίας έχει ξεπεράσει τους $0,7^o$ C. Ως τα τέλη του αιώνα, εάν δεν ληφθούν ουσιαστικά μέτρα αναμένεται αύξηση της θερμοκρασίας κατά 4 έως 6 βαθμούς. Είναι σημαντικό να επισημάνουμε ότι ακόμα και αν μειωθούν οι εκπομπές κατά 80% ως το 2050 οι κίνδυνοι και οι ζημιές δεν θα εξαλειφθούν σύμφωνα με την διακυβερνητική επιτροπή για την κλιματική αλλαγή (IPCC). Μπορούμε να περιμένουμε ελάττωση της χιονοκάλυψης με μείωση των μονίμων στρωμάτων πάγου και ακραία καιρικά φαινόμενα με κύματα καύσωνα, τροπικούς κυκλώνες και ισχυρότερες κατακρημνίσεις. Αλλά και μείωση των υδάτινων αποθεμάτων σε άνυδρες περιοχές στους τροπικούς και αύξηση σε περιοχές υγρές τροπικές μεγάλου γεωγραφικού πλάτους.

Η υγεία των ευάλωτων πληθυσμών που έχουν μικρότερη ικανότητα προσαρμογής πλήττεται σημαντικά, όπως ήδη φάνηκε στο καύσωνα στην Ευρώπη το 2003 και στον τυφώνα της Κατρίνα. Ο συνδυασμός της κλιματικής αλλαγής και της ατμοσφαιρικής ρύπανσης, καταστρέφει την γεωργική παραγωγή με αρνητικές συνέπειες στη παραγωγή τροφίμων.

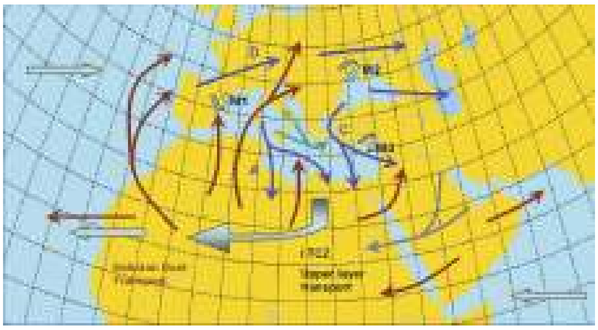
Οι επιπτώσεις της κλιματικής αλλαγής δεν αποτελούν ένα σενάριο επιστημονικής φαντασίας. Οι αυξημένες ξηρασίες ήδη αποτελούν αιτία μείωσης των αποθεμάτων γλυκού νερού. Τα οικοσυστήματα απειλούνται από τις μεταναστεύσεις των ζώων και των φυτών, την μειωμένη δασοκάλυψη, την αύξηση πλημμύρων, πυρκαγιών και ξηρασιών. Τα ζώα και τα φυτά απειλούνται με εξαφάνιση, ενώ εξωτικά φυτά και ζώα εισβάλλουν και εξαπλώνονται ανεξέλεγκτα εις βάρος των ενδημικών μορφών ζωής. Η απόδοση των καλλιεργειών και των αλιευμάτων μειώνεται με αποτέλεσμα την αύξηση της πείνας παγκοσμίως.

Η αύξηση των πλημμύρων, η διάβρωση των εδαφών και των τροπικών καταιγίδων επηρεάζουν διαφορετικά κάθε περιοχή. Έτσι, στην Β. Αμερική αναμένεται αύξηση θανάτων από καύσωνες. Στην Ασία είναι αυξημένος ο κίνδυνος πυρκαγιών με τις αντίστοιχες επιπτώσεις στο οικοσύστημα και λόγω της μείωσης των αποθεμάτων του γλυκού νερού 1 δισεκατομμύριο άνθρωποι κινδυνεύουν. Ειδικά στην νότια και ανατολική Ασία παρατηρείται αυξημένη θνησιμότητα και δυνητική μαζική εξάπλωση χολέρας. Στην Αφρική αναμένονται μειώσεις στην γεωργική απόδοση και 250 εκ. άνθρωποι μέχρι το 2020 δεν θα έχουν πρόσβαση σε πόσιμο νερό. Καταιγίδες και πλημμύρες θα απειλήσουν την Αυστραλία τα επόμενα χρόνια με σημαντική απώλεια της βιοποικιλότητας. Στην Λατινική Αμερική τα τροπικά δάση κινδυνεύουν να μετατραπούν σε σαβάνες με ταυτόχρονες εξαφανίσεις ειδών που αντίστοιχα θα απειλήσουν και την Ευρώπη στην οποία θα αυξηθούν οι κίνδυνοι θανάτων από καύσωνες (ΔΗΩ, 2009).

1.1 Το πρόβλημα στην Ανατολική Μεσόγειο

Στη λεκάνη της Μεσογείου λόγω της γεωγραφικής και κλιματικής της μορφολογίας ο ατμοσφαιρικός αέρας μαζί με τους ρύπους, αφενός μεν ποικίλει ποιοτικά με μεγάλη χρονική και χωρική μεταβλητότητα, αφετέρου μετακινείται από την Ευρώπη προς την ανατολική Μεσόγειο και την βόρεια Αφρική. Ενδεικτικά η σκόνη της Σαχάρας μεταφέρεται κατά το θέρος κυρίως από την Ασία και τον Ινδικό ωκεανό στην Αμερική (εικόνα 1 και εικόνα 2).

Εικόνα 6: Χαρακτηριστικές διαδρομές και κλίμακες της μεταφοράς των αερίων μαζών στην ευρωμεσογειακή περιοχή. Τα μωβ και τα πρασινωπά βέλη (A, B, C, και D) δείχνουν διαδρομές μεταφοράς των ανθρωπογενών ρύπων στην ευρωμεσογειακή περιοχή (όζον, θειικά, κλπ) στο κάτω τροπόσφαιρα. Τα γκρι βέλη που σχετίζονται κυρίως με το ανώτερο στρώμα μεταφοράς των ανθρωπογενών ρύπων. Ειδικότερα, τα μονοπάτια M1, M2, και M3 αντιστοιχούν στις θερμικές οδούς κυκλοφορίας στην περιοχή. Τα κόκκινο-καφέ βέλη δείχνουν τη μεταφορά της σκόνης της ερήμου από την περιοχή της Αφρικής μέχρι 5 χιλιόμετρα κάτω από το τροπόσφαιρα. (Πηγή: Kallos et al., 2006)



Στη Κωνσταντινούπολη, η οποία επεκτείνεται σε δυο ηπείρους και να διασχίζεται από τον Βόσπορο η κυκλοφορία του αέρα στην περιοχή επηρεάζεται από τους 7 λόφους (πάνω στους οποίους είναι χτισμένη), οι οποίοι έχουν ύψος πάνω από 1000 μέτρα. Η ατμοσφαιρικοί ρύποι από την Ευρώπη επηρεάζουν την μόλυνση της Κωνσταντινούπολης λόγω θέσης.

Το Κάιρο επηρεάζεται από βόρειο και νότιο δυτικό άνεμο. Οι βόρειοι είναι συχνότεροι το καλοκαίρι. Οι εκπομπές ρύπων στην ατμόσφαιρα είναι ιδιαίτερα αυξημένοι λόγω της έλλειψης καταλυτών και ειδικών φίλτρων στα αυτοκίνητα, σε συνδυασμό με τη κυκλοφοριακή συμφόρηση που αντιμετωπίζει η πόλη. Παρά τη λήψη των μέτρων και τη σημαντική μείωση των επιπέδων του CO που έχει παρατηρηθεί από το 1995, το πρόγραμμα δεν ανταποκρίθηκε στις αναμενόμενες βελτιώσεις της ποιότητας του ατμοσφαιρικού αέρα.

Η Αθήνα έχει κατεύθυνση ΒΑ-ΝΔ κατά μήκος της δεξαμενής της μεσογείου, ο αερισμός της είναι φτωχός. Τα μελτέμια συντελούν στον καλό εξαερισμό της πόλης μειώνοντας τα επεισόδια μόλυνσης. Ο Σαρωνικός κόλπος απορροφά την πρωτογενή αστική μόλυνση σε συνδυασμό με O_3 (Kanakidou et al. 2011)

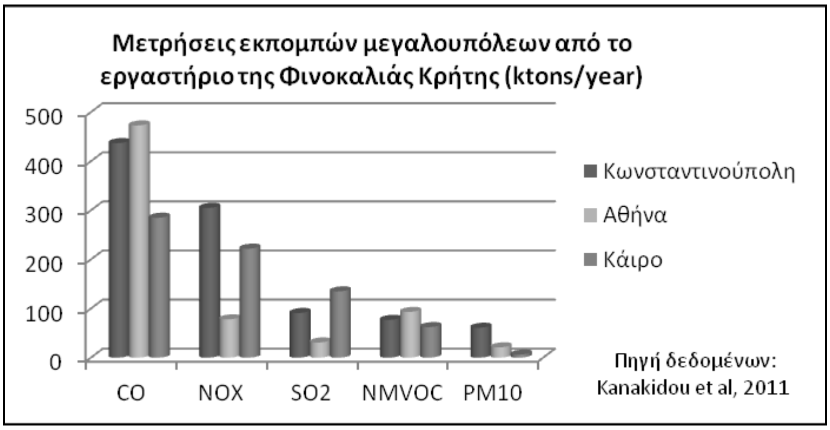
Μετρήσεις σε ύψος 700 μέτρων έγιναν για να ορίσουν την πορεία της μόλυνσης στην ατμόσφαιρα της Κωνσταντινούπολης, του Καΐρου και της Αθήνας βασίστηκαν σε από 30ετιας εξάωρες μετρήσεις με 2.5 ανάλυση. Η μόλυνση της Κωνσταντινούπολης επεκτείνεται κυρίως σε κατεύθυνση ΒΑ - ΝΔ, του Καΐρου Ν-ΝΔ στην αραβική χερσόνησο. Παρόμοια ο καπνός στην Αθήνα μεταφέρεται κυρίως ΝΑ.

Και οι τρεις πόλεις αντιμετωπίζουν μεγάλα επίπεδα ρύπανσης, η Αθήνα έχει πάνω από 2 εκ. αυτοκίνητα τα οποία αυξάνονται με ρυθμό 7% ετησίως, το Κάιρο 1 εκ. και η Κωνσταντινούπολη 2 εκ. με ποικιλία ποιότητας τεχνολογίας (τα παλαιότερο συναντώνται στο Κάιρο). Οι εκπομπές του Σαββατοκύριακου είναι χαμηλότερες απ' ότι τις εργάσιμες ημέρες της εβδομάδας και η αύξηση τους συμπίπτει με τις ώρες αιχμής, λόγω της συμβολής των εκπομπών κυκλοφορίας. Οι βιομηχανικές παραγωγές SO_2 αντιπροσωπεύουν το 30% του SO_2, ενώ η οδική κυκλοφορία είναι η κύρια αιτία της αύξησης CO, NOx και μη πτητικών οργανικών ενώσεων (NMVOCs) στην Κωνσταντινούπολη και στην Αθήνα.

Αντίθετα, το Κάιρο η καύση στις κατοικίες και βιομηχανίες είναι οι κύριες πηγές εκπομπής CO και NOx λαμβάνοντας υπόψη ότι οι εκπομπές NMVOC είναι ως επί το πλείστον από διαλύτες από τις οδικές μεταφορές. Ένα σημαντικό τμήμα των NOx (W50%) και SO_2 (W71%) προέρχεται από βιομηχανικές δραστηριότητες. Η κυκλοφορία είναι επίσης μια σημαντική πηγή για CO (35%), NMVOC (37%) και PM 2,5 (36%) (διάγραμμα 1).

Ανθρωπογενείς PM 2.5 στην GCA (Greater Cairo Area) προέρχονται κατά κύριο λόγο (54%) από ανοικτές καύσεις. Ελεύθερη καύση είναι μια κοινή πρακτική και μια σημαντική πηγή ρύπανσης του αέρα στην Αίγυπτο, όπως επίσης και σε αεροζόλ οπτικού βάθους (Aerosol Optical Depth-AOD) με εποχικότητα που προέρχεται από δορυφορικά δεδομένα με αύξηση το φθινόπωρο.

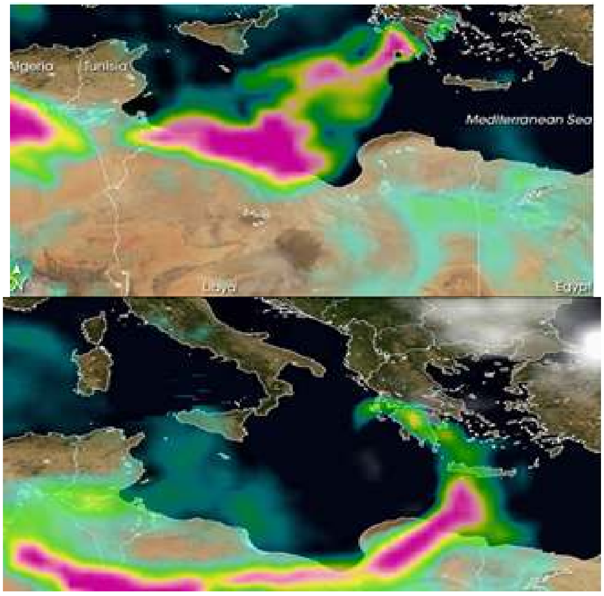
Διάγραμμα 1: Μετρήσεις εκπομπών από το εργαστήριο της Φινοκαλίας στη Κρήτη



Στην Αθήνα κύρια αιτία της ατμοσφαιρικής ρύπανσης παραμένει το αυτοκίνητο, λόγω της παλαιότητας των οχημάτων. Η χρήση του φυσικού αερίου, αν και σταδιακά αυξάνεται περιορίζεται ακόμα στην θέρμανση. Το όρος Αιγάλεω ευτυχώς διαχωρίζει φυσικά την βιομηχανική περιοχή από την πόλη και εμποδίζει την ανταλλαγή ρύπων.
Μελέτες του υπουργείου περιβάλλοντος από το 1987 μέχρι και το 1997 ληφθείσες ανά τριετία έδειξαν πτωτική τάση των ρύπων σε όλους σχεδόν τους σταθμούς. Το κέντρο της GAA (Greater Athens Area) για το SO_2, CO, NOx και μαύρο καπνό, εμφανίζει μείωση της τάξης του 52%, 34%, 26% και 20% αντίστοιχα. Οι συγκεντρώσεις των δευτερευόντων αέριων ρύπων παρέμειναν ουσιαστικά στα ίδια επίπεδα με το 1990, αν και με διαφορετικά χαρακτηριστικά (Parrish et al., 2009).

Η Μεσόγειος αποτελεί μια από τις περιοχές με την μεγαλύτερη AOD ιδιαίτερα πάνω από το Αιγαίο και την Μαύρη θάλασσα που τη καθιστά ορατή και από το διάστημα. Η μικρή διάρκεια ζωής των αιωρούμενων σωματιδίων (PM) στην τροπόσφαιρα είναι της τάξης της μιας εβδομάδας και ευθύνεται για την μεταβλητότητα στην περιοχή. Παρατηρήσεις το 2005 και 2006 με τον MISR (Multiangle Imaging Spectro Radiometer) και MODIS (Moderate Resolution Imaging Spectroradiometer), χρησιμοποιώντας τα στοιχεία Giovanni καθημερινά της NASA GES DISC έδειξαν ότι στα 443 nm υποδηλώνουν, ότι υπάρχει ένα σημαντικό ποσοστό λεπτών σωματιδίων (περίπου 0.5-0.6) που σχετίζονται με τις ρυπογόνες πηγές. Η συνδυασμένη ανάλυση των MODIS, AOD και των δεδομένων σωματιδίων δείκτη TOMS, που χρησιμοποιείται ως υποκατάστατο για την απορρόφηση της σκόνης αεροζόλ, μας έδωσε μια πρώτη εικόνα της συμμετοχής των ανθρωπογενών ρύπων τοπικά και την συμμετοχή τους στο AOD πάνω από το GAA και GCA σε 15-30% και 25-50%, αντίστοιχα, κατά το θέρος (Hatzianastassiou et al., 2009). Παρατηρούνται υψηλές συγκεντρώσεις αερολυμάτων, PM10 και PM 2.5, με αναλογία PM2.5/PM10 περίπου 0,5 (Querol et al., 2009).

Εικόνα 7: Δορυφορική εικόνα: Στις 27 του Αυγούστου 2007, τα αερολύματα από τις πυρκαγιές διέσχισαν τη Μεσόγειο Θάλασσα, όλη την Κρήτη, και πάνω ανατολική Λιβύη και την Αλγερία. (Πηγή: NASA)



2. Αίτια – Επιπτώσεις

Στα αίτια της κλιματικής αλλαγής συμπεριλαμβάνονται φυσικές και ανθρωπογενείς αιτίες, η αλυσίδα των αερίων του θερμοκηπίου (GHG- greenhouse gas). Οι παγκόσμιες εκπομπές των αερίων του θερμοκηπίου (GHG) που οφείλονται σε ανθρώπινες δραστηριότητες φαίνονται να έχουν αυξηθεί από τη προ βιομηχανική περιοχή με μια αύξηση της τάξης του 70% από τα έτη 1970-2004.
Οι ατμοσφαιρικές συγκεντρώσεις μεθανίου και οξειδίου του αζώτου υπερβαίνουν κατά πολύ τα φυσικώς αναμενόμενα σε ένα εύρος 650.000 ετών. Η παγκόσμια αύξηση του διοξειδίου του άνθρακα οφείλεται κυρίως στη χρήση ορυκτών καυσίμων και δευτερευόντως στην αλλαγή χρήσης γης.

Η παρατηρούμενη αύξηση της θερμοκρασίας της τροπόσφαιρας και ψύξη της στρατόσφαιρας πιθανότατα οφείλονται σε αύξηση των αερίων του θερμοκηπίου και μείωση του στρατοσφαιρικού όζοντος. Η παρατηρούμενη αύξηση του αερίου του θερμοκηπίου, θα μπορούσε να προκαλέσει ακόμα μεγαλύτερη αύξηση της θερμότητας, αν δεν ήταν η ψύξη από τα ηφαίστεια (IPCC, 2007).

Η όξινη βροχή (PH<5,6) είναι αποτέλεσμα αντιδράσεων οξειδίου του θείου και αζώτου με οξυγόνο και νερό, με αποτέλεσμα να δημιουργείται οξύ που καταστρέφει φυλλώματα δέντρων, ποιότητα εδάφους, τα φυσικά ύδατα και υδρόβιους οργανισμούς, κτίρια κλπ..

Η Πέμπτη Έκθεση αξιολόγησης της αλλαγής του κλίματος ανακοινώσε στις 27/9/2013. «Η υπερθέρμανση του πλανήτη είναι αδιαμφισβήτητη και μετά από το 1950 οι αλλαγές είναι άνευ προηγουμένου. Οι ωκεανοί θερμάνθηκαν, η στάθμη της θάλασσας έχει αυξηθεί και οι συγκεντρώσεις των αερίων του θερμοκηπίου αυξήθηκαν σημαντικά». Το διάστημα 1983-2012 για το βόρειο ημισφαίριο αποτελεί την θερμότερη τριακονταετή από τα τελευταία 1400 χρόνια. Οι παγκόσμιοι μέσοι όροι θερμοκρασιών συνδυασμένα γης και ωκεανού δείχνουν αύξηση θερμοκρασίας 0,85^{o}C από το 1880-2012. Ακόμα και οι ωκεανοί κάτω από τα 3000 μέτρα ως τον βυθό φαίνεται να έχουν ζεσταθεί τα τελευταία σαράντα χρόνια ιδιαίτερα στον νότιο ωκεανό. Επιπροσθέτως η άνοδος του επιπέδου της θάλασσας από το μέσο του 19ου αιώνα είναι μεγαλύτερη από την μέση αύξηση των δυο προηγούμενων χιλιετιών Από το 1901-2012 η μέση άνοδος της επιφάνειας της θάλασσας είναι 0,19 μ. Σύμφωνα με όλα τα σενάρια ο ρυθμός ανόδου της μέσης στάθμης της θάλασσας είναι πολύ πιθανό να υπερβαίνει εκείνη που παρατηρήθηκε κατά τη διάρκεια του 1971-2010, από την αύξηση της θερμοκρασίας των ωκεανών και την αύξηση της απώλειας μάζας από τους πάγους.

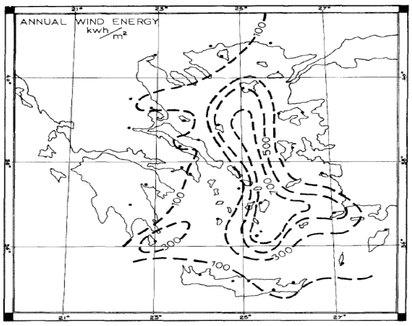
Από την προ-βιομηχανική περίοδο οι συγκεντρώσεις διοξειδίου του άνθρακα έχουν αυξηθεί κατά 40% προερχόμενες κυρίως από εκπομπές ορυκτών καυσίμων. Το 30% των εκπομπών από ανθρωπογενείς πηγές έχουν απορροφηθεί από τους ωκεανούς, με αποτέλεσμα να παρατηρείται όξυνση των ωκεανών. Έχουν αυξηθεί υπέρμετρα οι συγκεντρώσεις διοξειδίου του άνθρακα (κατά 40% σε σχέση με την πριν προβιομηχανική περίοδο από τις καύσεις των καυσίμων κυρίως και από την χρήση γης δευτερογενώς), μεθανίου και οξειδίου του αζώτου. όξυνση των ωκεανών λόγω της απορρόφησης του 30% των ανθρωπογενώς παραγομένων αερίων του θερμοκηπίου.
Σε όλες τις μελέτες που πραγματοποιήθηκαν (μοντέλα ατμοσφαιρικά) οι συγκεντρώσεις του CO_2 φαίνεται να είναι υψηλότερες το 2100 έναντι των σημερινών δεδομένων. Η αύξηση της θερμοκρασίας στην επιφάνεια του πλανήτη στο τέλος του 21ου αιώνα είναι πιθανό να ξεπεράσει τον 1,5^{o}C, σύμφωνα με την πλειοψηφία των σεναρίων, μερικά των οποίων την τοποθετούν ακόμα και στους 2^{o}C. Η αντίθεση στην βροχόπτωση μεταξύ υγρών και ξηρών περιοχών και μεταξύ υγρών και ξηρών εποχών θα αυξηθεί (IPCC, 2013).

Η Μεσόγειος αποτελεί ένα κλειστό οικοσύστημα που περιβάλλεται από σημαντικές οροσειρές και υψηλές χερσονήσους. Το τυπικό μεσογειακό κλίμα χαρακτηρίζεται από ζεστά, ξηρά καλοκαίρια και ήπιους, βροχερούς χειμώνες. Η εξάτμιση είναι ιδιαίτερα υψηλή στην ανατολική λεκάνη, με αύξηση της αλατότητας.

Κατά την περίοδο του ψύχους χαρακτηρίζεται από χαμηλή κυκλοφορία με έντονη κυκλογενετικότητα (στροβιλισμούς) στην κεντρική Ευρώπη και τα Βαλκάνια. Την περίοδο της ζέστης, έχουμε υψηλό δείκτη στροβιλισμού και οι χαμηλών πιέσεων άνεμοι στον ατλαντικό ωκεανό επεκτείνονται πάνω από τη Ευρώπη. Η λεκάνη του Αιγαίου εκτείνεται περίπου 600 χλμ. με Β-Ν κατεύθυνση και στενεύει στα 200

χιλιόμετρα στο γεωγραφικό πλάτος της Αθήνας. Οι οροσειρές της Ελλάδας και της Ασίας περιορίζουν το χαμηλότερο στρώμα της ατμόσφαιρας. Κατά τους καλοκαιρινούς μήνες εμφανίζονται τα μελτέμια (βόρειοι άνεμοι- εικόνα 3). Αυτά είναι αποτέλεσμα της μετακίνησης των ανέμων από το στενό κανάλι του Αιγαίου λόγω της μεταφοράς του εγκλωβισμένου από τις βόρειες οροσειρές αέρα, προς τα βόρεια Βαλκάνια σαν αποτέλεσμα των υψηλών θερμοκρασιών στη Ν.Α. Ασία.
Το χειμώνα ο καιρός της ανατολική Ελλάδα επηρεάζεται από τις υψηλές πιέσεων από τον υποτροπικό αντικυκλώνα των Αζορών. Επιπροσθέτως, οι χαμηλές πιέσεις στην βόρεια αφρικανική έρημο και το κίνημα των υφέσεων βόρεια ή Νότια της Ευρώπης και της Μεσόγειου έχουν σαν αποτέλεσμα θύελλες τύπου «Bora» συχνές στο βόρειο Αιγαίο, ενώ θύελλες Scirroco στο νότιο Αιγαίο (Zerefos,1978).

Εικόνα 8: Ετήσια επιφάνεια υπολογισμού ανέμων (kWh/m 2) πάνω από τη ανατολική Ελλάδα (Πηγή: Zerefos, 1978)



2.1 Θερμοκρασιακές Μεταβολές

Παρατηρείται προοδευτική αύξηση της θερμοκρασίας από το βόρειο ημισφαίριο προς το νότιο. Όσο πιο θαλάσσιο ή ωκεάνιο είναι το κλίμα, τόσο μικρότερες μεταβολές θερμοκρασίας έχουμε, ενώ αντίθετα στα ηπειρωτικά κλίματα οι μεταβολές της θερμοκρασίας είναι μεγαλύτερες. Αντίθετα από τις περιοχές της Β. και Β.Δ. Ευρώπη, στη Ν.Δ. προς την Β.Α. Ευρώπη παρατηρούμε οι θερμοκρασιακές μεταβολές, με τροπικές νύχτες και θερμές ημέρες, εντός 24ώρου να αυξάνονται με 2-8 μέρες το έτος, ενώ κατά μήκος των μεσογειακών χωρών τα επεισόδια αυξάνονται σε 12-14 ημέρες. Στην Ελλάδα από την άλλη μεριά στις παραθαλάσσιες κυρίως περιοχές τα επεισόδια ακραίων θερμοκρασιών αυξάνονται από 15-38 ημέρες ανάλογα με την περιοχή. Στα ορεινά τμήματα της ελλαδικής χερσονήσου (800-850 m και άνω υψόμετρα) δεν έχουμε εμφάνιση τροπικών νυχτών και θερμών ημερών. Η Αθήνα κατατάσσεται στις πιο θερμές πρωτεύουσες με τις περισσότερες θερμές ημέρες και ψυχρές νύχτες (περίπου 38 ετησίως) (Fischer et al., 2009).

Αναμένεται άνοδος της θερμοκρασίας κατά 1^{o}C την 30ετία 2021–2050 (σε σχέση με την 30ετία 1961 – 1990) από τη νότια μέχρι και τη κεντρική Ευρώπη, ενώ τη περίοδο 2071-2100 τα φαινόμενα προβλέπεται να καταλάβουν το μεγαλύτερο μέρος του ευρωπαϊκού χώρου. Τη δεκαετία του 1990 η Ελλάδα γνώρισε τριπλασιασμό των καυσώνων σε σύγκριση με την προηγούμενη περίοδο 30 ετών (ΙΣΤΑΜΕ, 2006). Οι μοναδικές αξιόπιστες καταγραφές θερμοκρασίας, που καλύπτουν μία μακρά περίοδο για την Ελλάδα (1890 ως σήμερα), έχουν πραγματοποιηθεί από το Εθνικό Αστεροσκοπείο Αθηνών (ΕΑΑ). Ο Ιούνιος είναι ο μήνας με τη μεγαλύτερη και σταθερότερη αύξηση της θερμοκρασίας στην Αθήνα, ενώ η μέση διάρκεια των θερμών επεισοδίων στην πρωτεύουσα είναι τρεις ημέρες. Το καλοκαίρι του 2007 ήταν ιδιαίτερα θερμό και τον Ιούνιο του 2007 η Αθήνα δέχθηκε την επίδραση των θανατηφόρων κυμάτων καύσωνα με τιμές που έφτασαν τους 46,2^{o}C (26 Ιουνίου). Βίωσε τρία συνεχή κύματα υψηλών θερμοκρασιών και 15 άνθρωποι έχασαν τη ζωή τους από θερμοπληξία. Ωστόσο είχαν σημειωθεί στο παρελθόν και άλλα φαινόμενα κατά τα οποία οι τιμές θερμομέτρου έφτασαν σε υψηλά επίπεδα, όπως το 1916 παρουσιάζοντας την πιο υψηλή μέχρι τότε θερμοκρασία 43^{o}C, και το 1987 όπου μια ακόμη υψηλή τιμή θερμοκρασίας προκάλεσε τον θάνατο 2.000 ανθρώπων στην Ελλάδα. Η χρονιά αυτή αποτελεί την αφετηρία εκτεταμένης χρήσης των κλιματιστικών με αποτέλεσμα οι συνθήκες να γίνουν χειρότερες από την κατάρρευση των συστημάτων παραγωγής ηλεκτρικής ενέργειας. Μεγάλη προσοχή εφιστά το γεγονός πως τη συγκεκριμένη χρονιά (2007) ξεσπάνε πυρκαγιές σε τεράστιες εκτάσεις γης (WWF, 2009).

Ένα άλλο πολύ σοβαρό επακόλουθο των θερμοκρασιακών μεταβολών, είναι οι πολύ υψηλές θερμοκρασίες κατά το θέρος, που καθιστούν δύσκολη τη διαβίωση για ζωικούς και φυτικούς οργανισμούς. Το πρόβλημα μεγεθύνεται στις πόλεις, διότι εκεί εξαιτίας της πυκνής δόμησης (μεγάλη απορρόφηση της ακτινοβολίας από τα δομικά υλικά) και του μειωμένου πρασίνου (ειδικά στο κέντρο της Αθήνας) οι θερμοκρασίες είναι υψηλότερες κατά 0,5-3^{o}C. Τα ακραία καιρικά φαινόμενα που είναι απόρροια των μεγάλων αυξομειώσεων της θερμοκρασίας με δυσμενείς επιπτώσεις στον άνθρωπο και το περιβάλλον ονομάζονται κλιματική καταστροφή (climatic disaster) (Wassen, 2009).
Το χειμώνα Νοτιοανατολικοί άνεμοι μεταφέρουν ζεστές αέριες μάζες πάνω από τη λεκάνη της Αθήνας, (αντικυκλωνικές συνθήκες με ασθενείς ανέμους πάνω από τα χαμηλά τροποσφαιρικά επίπεδα). Παρόμοιες αντικυκλωνικές συνθήκες επηρεάζουν τις θερμοκρασιακές διαφορές μεγάλων πόλεων, όπως Μπουένος Άιρες και Αργεντινή, με τη διαφορά ότι οι αέριες μάζες στην Αθήνα είναι μάλλον ξηρές (Kassamenos and Katsoulis, 2006).

2.2 Θερμική Νησίδα

Η μεγάλη αστικοποίηση επηρεάζει άμεσα το τοπικό κλίμα. Μετά το 1970 η απρογραμμάτιστη αστικοποίηση προκάλεσε μεγάλα περιβαλλοντικά προβλήματα όπως μεταφορά της ακτινοβολίας, αύξηση θερμοκρασίας, και υγρασίας. Διαπιστωθεί αύξηση της καταναλωμένης ενέργειας, αλλά και της ποιότητας του αέρα. Στις αστικές περιοχές εμφανίζονται υψηλότερες θερμοκρασίες από τις γύρω περιοχές.

Η τροποποίηση του ισοζυγίου της ακτινοβολίας επηρεάζει επιπροσθέτως την υγρασία με σημαντικές διαφορές μεταξύ αστικής νησίδας και των γύρω αγροτικών περιοχών (Holmer et Eliasson 1999). Στην αστική περιοχή η ηλιακή ακτινοβολία μετατρέπεται ως επί το πλείστον σε θερμότητα. Η ακτινοβολία στην Αθήνα, είναι υψηλή με διακύμανση από 22 MJ/m2 το καλοκαίρι σε 8MJ/m2 τον χειμώνα και συντελεί στην κυκλοφορία της θαλάσσιας αύρας κατά μήκος του ΝΔ-ΒΑ άξονα της λεκάνης (Kassamenos and Katsoulis, 2006).

Στο γεγονός αυτό συντελούν τα υλικά από τα οποία είναι φτιαγμένοι οι δρόμοι, τα πεζοδρόμια αλλά και τα κτίρια. Στην αγροτική περιοχή αντίθετα, η βλάστηση (η οποία εμπεριέχει νερό) που υπάρχει συντελεί στην μείωση της αύξησης της θερμοκρασίας της περιοχής από ηλιακή ακτινοβολία. Κατά την νύχτα η θερμοκρασία που έχει παγιδευτεί στο έδαφος εμφανίζεται στην ατμόσφαιρα σαν εξερχόμενη γήινη ακτινοβολία με συνέπεια την ταχεία ψύξη της περιοχής. Στην πόλη αντίθετα, η θερμότητα παγιδεύεται στα δομικά υλικά με αποτέλεσμα ο ρυθμός ψύξης της αστικής περιοχής συγκριτικά να είναι πιο χαμηλός (Gedzelman et al,2003).

Το λεκανοπέδιο της Αττικής, όπως στις αστικές νησίδες παγκοσμίως, παρατηρείται αύξηση της θερμοκρασίας μέχρι και 10^{o}C σε σχέση με την ύπαιθρο, εξαιτίας της πυκνής δόμησης με χαμηλά ποσοστά χώρων πρασίνου που τις καθιστά πιο επιρρεπής σε έντονα θερμά επεισόδια.

2.3 Περιοχές πρασίνου

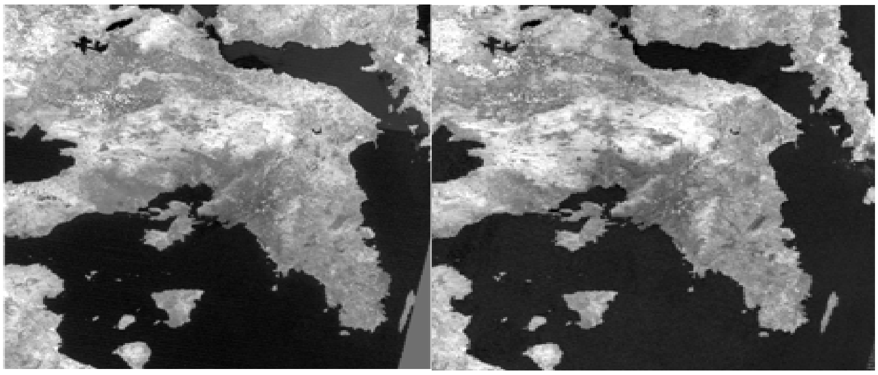
Οι χώροι πρασίνου παγκοσμίως έχουν μειωθεί με αποτέλεσμα οι πόλεις, ιδιαίτερα στα κέντρα να αντιμετωπίζουν έντονα περιβαλλοντικά προβλήματα. Οι χώροι πρασίνου συνεισφέρουν σημαντικά στη σωματική και ψυχική υγεία, μέσω της ενεργητικής και παθητικής αναψυχής, αλλά κυρίως μέσω της μείωσης της αέριας ρύπανσης, της ηχορύπανσης και του μικροκλίματος. Το κόστος συντήρησης των χώρων πρασίνου ωστόσο, σε συνδυασμό με την υψηλή αξία της γης, οδηγεί σταδιακά σε εξαφάνισή τους. Η Αθήνα έχει 2,55 τμ. πρασίνου ανά κάτοικο, η Ρώμη 9 τμ., το Βερολίνο 13 τμ, το Παρίσι 9,54 τμ. και το Άμστερνταμ 27 τμ.. Σύμφωνα με μελέτες που έχουν γίνει η προτεινόμενη αντιστοιχία πρασίνου ανά κάτοικο είναι 15,5 τμ. (Καλαβρυτινός, 2006).

Συγκεκριμένα στο λεκανοπέδιο Αθηνών, σύμφωνα με την έκθεση του γεωτεχνικού επιμελητηρίου Ελλάδας, στο σύνολο των 44 χλμ. έκτασης, οι πράσινοι χώροι καλύπτουν μόνο 4 τμ. λιγότερο από τα 10% της έκτασης του δήμου. Το πρόβλημα επιτείνεται, λόγω αφενός μεν κακού σχεδιασμού, αφετέρου δε λόγω της εγκατάλειψης τους, το ποσοστό φυτομάζας είναι μόνο 2,8-3% της συνολικής επιφάνειας του δήμου. Ενδεικτικά, στη περιοχή του Κολωνού μελέτη του 2009 έδειξε αναλογία πρασίνου ανά κάτοικο μόνο 1,68 τμ. Στο δήμο του Πειραιά από την άλλη μεριά το ποσοστό μειώνεται σε 1,56 ανά κάτοικο.

Την περίοδο του 1987-2007, 184.187 στρέμματα δασικής έκτασης μετά από πυρκαγιές μετατράπηκαν σε άλλου είδους καλύψεις. Την ίδια περίοδο οι οικισμοί επεκτάθηκαν κατά 191.124 στρέμματα, τα μισά από τα οποία κατέλαβαν φυσικές εκτάσεις. Το 2007 η μεγάλη πυρκαγιά στη Πάρνηθα έκαψε 49.000 στρέμματα δασών και κατέστρεψε τα 2/3 του ελατοδάσους τους εθνικού δρυμού, ενώ τον Αύγουστο του 2009 κάηκαν στην βορειοανατολική Αττική 205.210 στρέμματα κυρίως δασικής έκτασης (Μπελαβίλας, 2012).

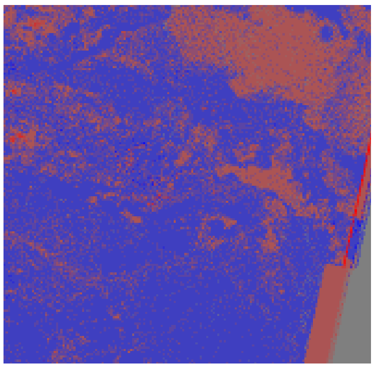
Ο δείκτης βλάστηση μπορεί να ποσοτικοποίηση την πυκνότητα των φυτών, υπολογίζεται με την εγγύς υπέρυθρη ακτινοβολία μείον την ορατή ακτινοβολία δια της εγγύς υπέρυθρη ακτινοβολία συν της ορατή ακτινοβολία [NDVI = (NIR- VIS)/ (NIR + VIS)]με τη χρήση δορυφορικών δεδομένων (ESA). Μελετώντας το δείκτη βλάστησης (NDVI- εικόνα 4) με τη χρήση δορυφορικών εικόνων Landsat της Αττικής παρατηρούμε τις περιοχές με βλάστηση (pixel με μεγαλύτερη φωτεινότητα- ανακλούν την ακτινοβολία), αντίθετα η έλλειψη πρασίνου απεικονίζεται με pixel που απορροφούν την ακτινοβολία (σκουρόχρωμες περιοχές). Μελετήσαμε δύο χρονικές περιόδους μιας δεκαετίας 1991 και 2001 με σκοπό να παρατηρήσουμε τις αλλαγές που έχει υποστεί το αστικό πράσινο.

Εικόνα 9: NDVI λεκανοπεδίου Αττικής 1991 (δεξιά) και 2001 (αριστερά)



Εντός της δεκαετίας 1991-2001 παρατηρούνται διάφορες αλλαγές στην βλάστηση οι οποίες απεικονίζονται (change detection- εικόνα 5) με διαβαθμίσεις του μαύρου και γκρι χρώματος. Με μπλε χρώμα εμφανίζονται οι αρνητικές αλλαγές στην βαθμοανάκλαση του πρασίνου, που σηματοδοτεί την εξαφάνιση του πρασίνου στις περιοχές αυτές σε εύρος μιας δεκαετίας. Τα pixel με κόκκινο χρώμα παρουσιάζουν θετικές αλλαγές οι οποίες μπορεί να οφείλονται σε κλιματικές αλλαγές ή ακόμα και σε αύξηση του πρασίνου. Όσο πιο σκούρο είναι το χρώμα τόσο πιο έντονη είναι η αλλαγή που έχει υποστεί (θετική-αρνητική). Οι μεταβολές εντός της δεκαετίας συμπεριλαμβάνουν τόσο την γήινη επιφάνεια όσο και την υδάτινη. Οι αρνητικές μεταβολές με μπλε χρώμα που φαίνονται στον υδάτινο ορίζοντα οφείλονται τόσο σε θερμοκρασιακές μεταβολές όσο και έλλειψη χλωροφύλλης.

Εικόνα 10: Change detection της δεκαετίας 1991-2001



2.4 Επιπτώσεις στην υγεία

Η ατμοσφαιρική ρύπανση δεν έχει άμεσα αισθητές επιπτώσεις στον άνθρωπο και ο τρόπος που επηρεάζει εξαρτάται από το φύλο, την ηλικία του ατόμου, τη χωρητικότητα των πνευμόνων του, το διάστημα παραμονής στη μολυσμένη ατμόσφαιρα και το μέγεθος των σωματιδίων των ρύπων.

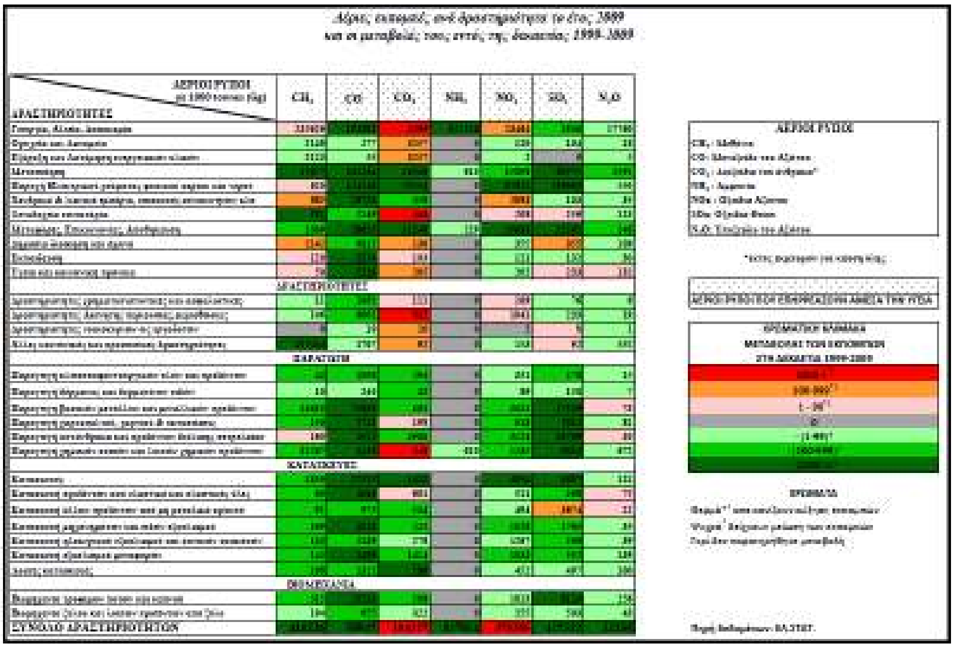
Οι βασικότερες επιπτώσεις αφορούν τους πνεύμονες και την καρδία. Η ατμοσφαιρική ρύπανση ευθύνεται για 450.000 πρόωροι θάνατοι ετησίως στην Ευρώπη. Μελέτες έχουν δείξει ότι πιο τρωτός είναι ο πληθυσμός με χαμηλότερα εισοδήματα, λόγω του ότι ζουν σε κτήρια με ανεπαρκή προστασία από την αυξημένη θερμότητα, καθώς και ευπαθής ομάδες, παιδία, άρρωστοι, ηλικιωμένοι (Σαπουτζάκη, 2007).

Οι ατμοσφαιρικοί ρύποι χωρίζονται στους πρωτογενείς ρύπους οι οποίοι εκλύονται απευθείας στον αέρα και στους δευτερογενείς οι οποίοι δημιουργούνται από αντιδράσεις μεταξύ των πρωτογενών ρύπων.

Στους πρωτογενείς ανήκει το μονοξείδιο του άνθρακα (CO) με το 95% του ποσού να εντοπίζεται στις πόλεις λόγω των κινητήρων εσωτερικής καύσης και τα αυτοκίνητα και προκαλεί ζάλη, ακόμα και μείωση πνευματικής διαύγειας. Το διοξείδιο του άνθρακα (CO2) επηρεάζει το μεταβολισμό ασβεστίου και φωσφόρου και είναι τοξικό για τη καρδιά και προκαλεί παραισθήσεις και απώλεια συνείδησης. Τα οξείδια του αζώτου (NO, NO_2, N_2O) συμβάλουν στον στη δημιουργία όξινης βροχής και προκαλούν βλάβες στο αίμα, το ήπαρ, τους πνεύμονες και το σπλήνα. Από τα αιωρούμενα σωματίδια, όπως η σκόνη, ο καπνός και διάφορα μέταλλα προέρχονται από διάφορες βιομηχανικές δραστηριότητες, αλλά και πυρκαγιές και καψαλίσματα. Σημαντικό ρόλο παίζουν τα σωματίδια μέχρι 10μm (PM-10) γιατί το μέγεθός του επιτρέπει την είσοδό τους στο αναπνευστικό σύστημα και έτσι προκαλούν καρδιοαναπνευστικά προβλήματα, ιδιαίτερα το καλοκαίρι που πνέουν νότιοι ασθενείς άνεμοι και επικρατεί άπνοια με αποτέλεσμα να εντοπίζονται υψηλές συγκεντρώσεις στο κέντρο της Αθήνας. Από τους υδρογονάνθρακες το πιο επικίνδυνο είναι το βενζόλιο που μπορεί να προκαλέσει μεταξύ των άλλων καρκίνο, αλλά και προβληματικές γεννήσεις (ΚΕΕΛΠΝΟ).

Στους δευτερογενείς ρύπους ανήκει το νέφος της αιθαλομίχλης (εμφανίζεται το χειμώνα)και το φωτοχημικό νέφος (εμφανίζεται το καλοκαίρι), προκαλούν αναπνευστικά προβλήματα, αλλά και βλάβες στα φυτά. Η μακροχρόνια έκθεση, ακόμα και σε χαμηλά επίπεδα όζοντος επιδρά βλαβερά στους πνεύμονες και στα μάτια.
Οι εκπομπές των αερίων ρύπων παρουσιάζονται στην παρακάτω περιβαλλοντική μήτρα. Οι ρύποι εκφράζονται σε 1000 τόνους (Gg) ανά δραστηριότητα και με τη χρωματική κλίμακα φαίνεται αν εμφανίζουν μείωση ή αύξηση συγκριτικά με το 1999. Παρατηρούμε ότι η αλιεία, δασοκομία και γεωργία έχουν αυξήσει τις εκπομπές του CO_2 σύμφωνα με μετρήσεις της ΕΛ. ΣΤΑΤ., όπως επίσης παρατηρείται αύξηση των εκπομπών για ξενοδοχειακές δραστηριότητες και δραστηριότητες εστίασης. Τέλος, οι εκπομπές CO_2 έχουν αυξηθεί και από τη παραγωγή χημικών ουσιών και λοιπών χημικών προϊόντων (όπως μπορούμε να δούμε με κόκκινο χρώμα στο Πίνακα 1). Όσον αφορά το σύνολο των δραστηριοτήτων σημαντική αύξηση παρατηρείται στο διοξείδιο του άνθρακα, αλλά και στο οξείδια του αζώτου εντός της δεκαετίας 1999-2009.

Πίνακας 3: Περιβαλλοντική μήτρα με τις εκπομπές των αερίων ανά δραστηριότητα το έτος 2009 και οι μεταβολές εντός της δεκαετίας 1999-2009



3. Συμπεράσματα –Αποτελέσματα

Η κακή χρήση και σπατάλη των φυσικών πόρων, η υπερβολική κατανάλωση του υπέργειου και υπόγειου πλούτου σε όλες τις μορφές του, αλλά και η αλόγιστη χρήση της τεχνολογίας με μόνο κριτήριο το κέρδος, οδήγησε όλο το πλανήτη σε μια κατάσταση κινδύνου πολύ κοντά στο μη αναστρέψιμο. Η αστικοποίηση οδήγησε στη δημιουργία πόλεων «θερμοκήπια» με αστικές νησίδες χωρίς πράσινο και χώμα, με αύξηση θερμοκρασιών. Τα αέρια του θερμοκηπίου διατηρούνται πλέον σε υψηλά επίπεδα και η υπερθέρμανση του πλανήτη με όλα τα επακόλουθα για την υγεία, το περιβάλλον και τη ζωή στο πλανήτη να είναι πραγματικότητα.

Στην Αθήνα η πυκνή δόμηση δημιουργεί έντονα φαινόμενα αστικής νησίδας λόγω της μεγάλης εκμετάλλευσης της γης για οικονομικό κέρδος, με συνέπεια την έλλειψη χώρων πρασίνου και την αύξηση τόσο της θερμοκρασίας, όσο και των αέριων ρύπων. Τα ακραία καιρικά φαινόμενα αυξάνονται και οι ομαλές μεταβάσεις των εποχών φαίνονται να μην υπάρχουν.

Οι καρκινογενέσεις, η αύξηση καρδιακών και αναπνευστικών προβλημάτων οφείλονται στην ατμοσφαιρική ρύπανση. Με βάση τα στοιχεία που μελετήσαμε φαίνεται πως όπου λαμβάνονται μέτρα επιτυγχάνεται μείωση των εκπομπών, αλλά τα συμφέροντα δεν επιτρέπουν στα μέτρα να είναι ουσιαστικά.

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Ευρωπαϊκή και Ελληνική Πολιτική Βιώσιμης Αστικής Κινητικότητας και Δείκτες Αστικής Αειφορίας

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Περίληψη
Η προστασία του περιβάλλοντος και η αντιμετώπιση των συνεπειών της κλιματικής αλλαγής αποτελούνε σήμερα αντικείμενο παγκόσμιας ενασχόλησης. Η ανθρωπότητα διείδε ότι η ασύστολη χρήση των φυσικών πόρων οδηγεί στη ραγδαία υποβάθμιση της ποιότητας ζωής των μελλοντικών γενεών. Στην παρούσα εργασία αναλύεται η Ευρωπαϊκή και η Ελληνική πολιτική για τη δημιουργία ενός βιώσιμου αστικού περιβάλλοντος με έμφαση στις βιώσιμες αστικές μετακινήσεις. Επεξηγείται η Νέα Ευρωπαϊκή πολιτική που στοχεύει προς ένα νέο πολιτισμό για τις αστικές μετακινήσεις και παρουσιάζεται η σύγχρονη στρατηγική βιώσιμης αστικής κινητικότητας στις ελληνικές πόλεις. Παράλληλα, επεξηγείται η έννοια της βιώσιμης κινητικότητας, καθώς και η ιστορική της εξέλιξη. Παρατίθενται οι δείκτες αειφορίας των πόλεων, καθώς και οι δείκτες αποτίμησης της βιώσιμης κινητικότητας, όπως κατανέμονται σε τρεις κατηγορίες: οικονομικοί, κοινωνικοί και περιβαλλοντικοί. Στόχος της εργασίας είναι η υποστήριξη της άποψης πως οι αστικές μετακινήσεις πρέπει να συμβάλλουν στη δημιουργία πόλεων όχι απλά βιώσιμων, αλλά αξιοβίωτων. Οι πολίτες οφείλουν να απολαμβάνουν κοινωνική και οικονομική ισότητα, ώστε η οικονομία να αναπτύσσεται πλέον με όρους βιωσιμότητας και όχι απλά με όρους οικονομικής μεγέθυνσης.
Λέξεις κλειδιά: Πολιτική μεταφορών, αειφορία, δείκτες, περιβάλλον, κοινωνία, οικονομία
JEL κωδικοί: R4, R41, O2, O20.

Abstract
Environmental protection and negative impacts reduction of climate change represent an important issue for scientists worldwide. Humanity realized that a continuously raise of natural resources consumption could reduce the quality of living standards for future generations. This research analysis the current European and Hellenic policy to develop a sustainable urban environment based on sustainable transportation modes. The new European and Hellenic urban transportation policy is presented. Also, the term of sustainable transportation, its historical evolution, and urban sustainability indicators: financial social and environmental are presented. The target of this research is to the support the opinion that urban transportation should involve in the development of cities not only sustainable but worth living ones. Citizens should enjoy social and financial equity in order the economy to develop under sustainability terms and not just grow.
Keywords: Transport policy; Sustainability; Indicators, Environment; Social, Economy.
JEL classificationS: R4; R41; O2; O20.

1. Βιώσιμη κινητικότητα

1.1 Βιώσιμη Κινητικότητα: Ορισμός

Τα βιώσιμα μέσα μετακίνησης συνεισφέρουν στην περιβαλλοντική, κοινωνική και οικονομική βιωσιμότητα των κοινωνιών στις οποίες εντάσσονται. Δεν υπάρχει κοινά αποδεκτός ορισμός της έννοιας της βιώσιμης κινητικότητας. Ένας από τους πιο διαδεδομένους είναι ότι ένα βιώσιμο μέσο μεταφοράς αποτιμάται από το «πως τα περιβαλλοντικά, οικονομικά και κοινωνικά συστήματα αλληλεπιδρούν με βάση αμοιβαία πλεονεκτήματα ή μειονεκτήματα σε ποικίλες χωρικές κλίμακες λειτουργίας» (Towards a Sustainable Future, 1997). Με βάση τον Οργανισμό για την Οικονομική Συνεργασία και την Ανάπτυξη (ΟΟΣΑ), το «Καναδικό Κέντρο για τις Βιώσιμες Μεταφορές» (Centre for Sustainable Transport - CST), αλλά και την Ευρωπαϊκή Επιτροπή των Υπουργών Μεταφορών, ένα βιώσιμο σύστημα μεταφορών είναι αυτό που:

Καλύπτει τις ανάγκες της προσβασιμότητας και κινητικότητας τόσο σε ατομικό όσο και σε κοινωνικό επίπεδο, με τρόπο που δεν είναι επιβλαβής για τον άνθρωπο ή το περιβάλλον και με στόχο την προώθηση της ισότητας μεταξύ της παρούσας όσο και των μελλοντικών γενεών. Είναι επαρκές και αποτελεσματικό, προσφέρει εναλλακτικές επιλογές μεταξύ των μέσων μεταφοράς, υποστηρίζει μια ανταγωνιστική οικονομία και μια ισορροπημένη περιφερειακή ανάπτυξη. Μειώνει τις εκπομπές ρύπων και αποβλήτων εντός των ορίων του πλανήτη να τις απορροφήσει, χρησιμοποιεί μη ανανεώσιμες πηγές ενέργειας εντός των ορίων ανάπτυξης των ανανεώσιμων υποκατάστατών τους, ενώ τέλος ελαχιστοποιεί την κατανάλωση χώρου αλλά και τη δημιουργία θορύβου.

1.2 Βιώσιμη Κινητικότητα: Ιστορική Εξέλιξη

Τα πιο βιώσιμα μέσα μετακίνησης χρησιμοποιήθηκαν από τον άνθρωπο προτού ανακαλυφθεί αυτή η φράση. Το περπάτημα όντας το πρώτο μέσο μετακίνησης είναι εν τούτοις και το πιο βιώσιμο δημιουργώντας ένα παράδοξο στη συσχέτιση με την τεχνολογική πρόοδο που έχει επιτευχθεί σήμερα. Η χρήση της δημόσιας συγκοινωνίας ανάγεται στο παρελθόν με την εφεύρεση του δημόσιου λεωφορείου από τον Blaise Pascal. Ο πρώτος επιβατικός τροχιόδρομος (τραμ) ξεκίνησε τη λειτουργία του το 1807 στην Ουαλία (Μ. Βρετανία) και το 1832 στη Νέα Υόρκη (ΗΠΑ). Οι πρώτες επιβατικές σιδηροδρομικές γραμμές λειτούργησαν το 1825, λειτουργούσαν με ατμό και συνέδεαν τις πόλεις Stockton και Darlington στη βορειοανατολική Αγγλία. Η χρήση του ποδηλάτου ανάγεται από το 1860.

Τα ανωτέρω μέσα μεταφοράς ήταν τα πιο διαδεδομένα πριν το 2^{ο} Παγκόσμιο Πόλεμο. Μεταπολεμικά, η ραγδαία οικονομική ανάπτυξη οδήγησε και στην αύξηση της χρήσης του ΙΧ, τόσο στις ΗΠΑ όσο και στην Ευρώπη. Στόχος της πολιτικής των μεταφορών ήταν η πρόβλεψη της μελλοντικής ζήτησης για μεταφορικό έργο και η κάλυψη αυτής της ζήτησης με αντίστοιχη προσφορά οδικής υποδομής. Οι επενδύσεις για δημόσια συγκοινωνία, περπάτημα και χρήση του ποδηλάτου ήταν ελάχιστες έως μηδενικές στις ΗΠΑ σε αντίθεση με την Ευρώπη (Making transit work, 2001). Όμως η εξάρτηση των οδικών μεταφορών από τα ορυκτά καύσιμα και ιδίως το πετρέλαιο δημιούργησε διεθνή οικονομική ανησυχία κατά τη διάρκεια της πετρελαϊκής κρίσης που ακολούθησε τον πόλεμο του Γιομ Κιπούρ (1973) και της ενεργειακής κρίσης που ακολούθησε την ανατροπή του Σάχη της Περσίας από την ισλαμική επανάσταση (1979). Η σταθεροποίηση των τιμών του πετρελαίου τις δεκαετίες του ’80 και του ’90 αύξησε τη χρήση του αυτοκινήτου από τους πολίτες για τις καθημερινές τους μετακινήσεις, συμβάλλοντας και στην αύξηση του μεγέθους των πόλεων. Η αύξηση των εκπομπών αερίων του θερμοκηπίου, η κυκλοφοριακή συμφόρηση και οι αρνητικές τους επιπτώσεις στην ποιότητα ζωής στις πόλεις οδήγησαν στην αναζήτηση δράσεων για την προώθηση εναλλακτικών μέσων μετακίνησης (Kenworthy and Newman, 1999).

2. Δείκτες βιώσιμης κινητικότητας και αειφορίας

2.1 Δείκτες Βιώσιμης Κινητικότητας: Χρήση

Ο ορισμός της έννοιας της βιώσιμης κινητικότητας αποτελεί το πρώτο βήμα για τη δημιουργία δεικτών μέτρησης της δυνατότητας ενός συστήματος μεταφορών να συνεισφέρει στην πρόοδο μιας κοινωνίας προς την κατεύθυνση της βιωσιμότητας. Η κοινή διαπίστωση πως «ότι μπορεί να μετρηθεί μπορεί και να διαχειριστεί» μπορεί να εφαρμοστεί και για την αξιολόγηση της έννοιας της βιωσιμότητας. Η έννοια του «δείκτη μέτρησης» συνιστά μια «επιλεγμένη και καθορισμένη μεταβλητή για τη μέτρηση της προόδου ενός στόχου» (Gudmundsson, 2001). Οι δείκτες μέτρησης της βιώσιμης κινητικότητας ενσωματώνουν τη σχέση μεταξύ των τριών συστατικών στοιχείων της (οικονομία, κοινωνίας και περιβάλλον). Ένας κατάλληλος για το σκοπό αυτό δείκτης θα πρέπει να περιλαμβάνει τουλάχιστον δυο από τα τρία ανωτέρω χαρακτηριστικά, να αναγνωρίζει την αρνητική διάσταση ενός προβλήματος και να συμβάλλει στη διόρθωσή του (Hart, 2006). Ένας δείκτης πρέπει να μετρά τα χαρακτηριστικά μιας κατάστασης και να δημιουργεί βάσεις δεδομένων, ώστε να μπορεί να προβεί σε μελλοντικές συγκρίσεις και αξιολογήσεις ενός φαινομένου. Η βιώσιμη κινητικότητα μπορεί να αξιολογηθεί με βάση 17 δείκτες, οι οποίοι κατανέμονται ανάμεσα στους τρεις πυλώνες του περιβάλλοντος, της κοινωνίας και της οικονομίας (Gilbert et al, 2002).

2.2 Δείκτες Βιώσιμης Κινητικότητας: Οικονομικοί

Οι δείκτες οικονομικής βιωσιμότητας των μεταφορών αντανακλούν τα κόστη και τα οφέλη της χρήσης των μηχανοκίνητων οχημάτων, αλλά και την πιθανότητα η μηχανοκίνητη κυκλοφορία να συνιστά παράγοντα μείωσης της προσβασιμότητας. Η μονοσήμαντη ανάπτυξη ενός μέσου μεταφοράς συμβάλλει στη μείωση της κινητικότητας σε σχέση με τη δικτυακή ανάπτυξη και τη συνδυασμένη χρήση εναλλακτικών μέσων μεταφοράς.

Ο αριθμός των διανυθέντων οχηματοχιλιομέτρων και επιβατοχιλιομέτρων συνιστούν δυο δείκτες χρήσης των μηχανοκίνητων οχημάτων οι οποίοι μπορούν να θεωρηθούν και ως δείκτες βιωσιμότητας, εφόσον υποτεθεί ότι τα μηχανοκίνητα μέσα μεταφοράς είναι επιβλαβή για το περιβάλλον. Όμως αυτή η υπόθεση δεν είναι απόλυτη από οικονομικούς όρους, εφόσον η προσβασιμότητα μιας περιοχής με μηχανοκίνητα μέσα αυξάνει την ελκυστικότητα για επενδύσεις και την οικονομική ανάπτυξη. Επιπλέον, η βελτίωση της τεχνολογίας στην κατασκευή των οχημάτων, στη μείωση των εκπομπών καυσαερίου, καθώς και η βελτίωση των γεωμετρικών και λειτουργικών χαρακτηριστικών μιας οδού αποτελούν ενδείξεις σωστής κατεύθυνσης προς τη βιώσιμη κινητικότητα.

Η οικονομική βιωσιμότητα και βέλτιστη αποτελεσματικότητα ενός μέσου μεταφοράς σχετίζεται και με τη διαθέσιμη υποδομή. Ο υφιστάμενος σχεδιασμός των πόλεων στις ΗΠΑ αλλά και σε αρκετές ευρωπαϊκές πόλεις πριμοδοτεί τη χρήση του αυτοκινήτου μέσω αστικών αυτοκινητοδρόμων, της αραιής δόμησης στα προάστια και προσφέροντας θέσεις στάθμευσης σε οργανωμένους σταθμούς στο κέντρο των πόλεων. Ορισμένες μελέτες υποστηρίζουν ότι το 30% των μετακινήσεων με αυτοκίνητο οφείλεται σε αυτήν ακριβώς την αιτία (Litman T, 2009).

Συγκεκριμένες αποφάσεις μπορούν να αξιολογηθούν με κριτήριο τη βιωσιμότητα. Συγκεκριμένα, όταν σχεδιάζονται δράσεις που σχετίζονται με τη μείωση της κυκλοφοριακής συμφόρησης, αποφάσεις που ευνοούν τη χρήση του αυτοκινήτου και την αστική διάχυση θεωρούνται μη βιώσιμες, ενώ η εφαρμογή αστικών διοδίων και η επένδυση σε υποδομές για τους πεζούς, τους ποδηλάτες και τα μέσα μαζικής μεταφοράς θεωρούνται βιώσιμες. Εν τέλει, ένα μέσο μεταφοράς για να είναι βιώσιμο θα πρέπει να μπορεί να αποκτηθεί ή να χρησιμοποιηθεί από τη μεγαλύτερη μερίδα των πολιτών, να λειτουργεί αποτελεσματικά, να προσφέρει δυνατότητες διασύνδεσης με άλλα μέσα μεταφοράς και να ενσωματώνει στην τιμολόγησή του όλα τα εξωτερικά κόστη που προκαλεί στο περιβάλλον και την κοινωνία.

2.3 Δείκτες Βιώσιμης Κινητικότητας: Κοινωνικοί

Η κοινωνική ισότητα και δικαιοσύνη σε όρους βιωσιμότητας ενός μεταφορικού μέσου μπορεί να εκτιμηθεί με χαρακτηριστικά όπως η κάλυψη των βασικών αναγκών μετακίνησης των πολιτών με σεβασμό στις συλλογικές ανάγκες μετακίνησης του κοινωνικού συνόλου και τη μείωση των αρνητικών επιπτώσεων στην υγεία των πολιτών. Στόχος είναι η πρόσβαση κάθε χώρου με ασφάλεια και άνεση. Επίσης, η παροχή υψηλής ποιότητας εξυπηρέτησης από ένα μεταφορικό μέσο ή σύστημα και η δυνατότητα χρήσης από όλους τους πολίτες ανεξαρτήτως κοινωνικών, οικονομικών και σωματικών περιορισμών. Οι αρνητικές επιπτώσεις των οδικών μεταφορών στην υγεία των πολιτών όπως τα οδικά ατυχήματα, ο θόρυβος και η ατμοσφαιρική ρύπανση αντισταθμίζονται από την ενίσχυση του περπατήματος και του ποδηλάτου που θεωρούνται βιώσιμα μέσα μετακίνησης.

2.4 Δείκτες Βιώσιμης Κινητικότητας: Περιβαλλοντικοί

Οι περιβαλλοντικοί δείκτες βιωσιμότητας αξιολογούν τις επιπτώσεις των μεταφορικών συστημάτων στο περιβάλλον. Σχετίζονται με τις εκπομπές ρύπων στην ατμόσφαιρα και στα ύδατα σε ποσοστά που ο πλανήτης μπορεί να απορροφήσει, τη μείωση της κατανάλωσης μη ανανεώσιμων πρώτων υλών και πηγών ενέργειας, τη δυνατότητα ανακύκλωσης και την ελαχιστοποίηση της εδαφικής κατανάλωσης. Θεωρούνται επίσης δείκτες που σχετίζονται με την αλλαγή του τοπίου λόγω της χάραξης ενός νέου δρόμου, την αύξησης της θερμοκρασίας στον αστικό χώρο λόγω κάλυψης της οδικής επιφάνειας με άσφαλτο, ακόμα και τις επιπτώσεις στο οικοσύστημα λόγω του θανάτου σπάνιων ζώων από τροχαία ατυχήματα. Υπάρχουν αρκετές μέθοδοι που μπορούν να μετρήσουν τις περιβαλλοντικές επιπτώσεις των μεταφορών, όμως δε λαμβάνουν υπόψιν όλους τους ανωτέρω παράγοντες ώστε να παρέχονται αξιόπιστα και συγκρίσιμα αποτελέσματα.

2.5 Δείκτες Αστικής Αειφορίας

Το ζήτημα της αειφόρου ανάπτυξης και της βιώσιμης κινητικότητας απασχολεί αρκετά τις κοινωνίες. Εξετάζεται η έννοια της βιώσιμης κινητικότητας και πως μπορεί να μετρηθεί ποσοτικά και όχι απλώς ποιοτικά. Η απάντηση δίνεται με τη χρήση συγκεκριμένων δεικτών που έχουν αναπτυχθεί για συγκεκριμένους λόγους. Οι δείκτες αυτοί είναι περιβαλλοντικοί, οικονομικοί, κοινωνικοί και υγειονομικοί που δε θεωρούνται αποκλειστικά δείκτες αειφορίας, αλλά έχουν μια επεξηγηματική τιμή.

Πιλοτικά προγράμματα για την αποτίμηση της αειφορίας σε τοπικό επίπεδο έχουν ξεκινήσει σε διάφορες χώρες και πόλεις, ώστε να οριστούν οι δείκτες που είναι πλέον χρήσιμοι και αποτελεσματικοί. Το 1992 στην πόλη του Σηάτλ (ΗΠΑ) ξεκίνησε το πιλοτικό πρόγραμμα «Αειφόρο Seattle» με στόχο να εκτιμηθεί ποσοτικά ο βαθμός αειφορίας. Έτσι, τέθηκε για πρώτη φορά το ζήτημα των «δεικτών αειφορίας», δηλαδή μιας σειράς δεικτών με τους οποίους εκτιμάται πόσο αειφόρος είναι η ανάπτυξη μιας περιοχής (Sustainable Seattle and Indicators, 2004). Η πόλη της Κοπεγχάγης έχει ορίσει ένα δείκτη διαθέσιμων χώρων στάθμευσης οχημάτων, καθώς αυτό συνάδει με την αύξηση της οικονομικής δραστηριότητας και τη μείωση της μηχανοκίνητης κυκλοφορίας.

Οι δείκτες αειφορίας ομαδοποιούνται σε διάφορες κατηγορίες ανάλογα με τη γεωγραφική αναφορά από παγκόσμια κλίμακα έως την τοπική κλίμακα μιας πόλης. Οι δείκτες χρησιμοποιούν μετρήσιμα μεγέθη τα οποία παρέχουν μια εκτίμηση της κατάστασης των περιβαλλοντικών, κοινωνικών και αναπτυξιακών χαρακτηριστικών της περιοχής που σχετίζονται με τα προβλήματα της ποιότητας ζωής των πολιτών. Σύμφωνα με τους Kenworthy and Newman (1999), ζητήματα όπως η ενέργεια που καταναλώνεται από μια πόλη, η ποιότητα του αέρα, η κατανάλωση αστικού χώρου και το ποσοστό πρασίνου αποτελούν κριτήρια βιωσιμότητα μιας πόλης. Στον τομέα των αστικών μεταφορών η ποιότητα της οδικής υποδομής και η οδική ασφάλεια αποτελούν τομείς για την ανάπτυξη ανάλογων δεικτών, όπως το ποσοστό του πληθυσμού που χρησιμοποιεί δημόσια συγκοινωνία και το μήκος των πεζοδρόμων ή των δρόμων ήπιας κυκλοφορίας που αποδίδεται για τη μετακίνηση των πεζών.

Οι Spiekermann and Wegener (2003) περιγράφουν το ευρωπαϊκό ερευνητικό πρόγραμμα PROPOLIS (Planning and Research of Policies for Land Use and Transport for Increasing Urban Sustainability), στο οποίο έχουν αναπτυχθεί ορισμένοι δείκτες αστικής βιωσιμότητας. Εννέα θεματικές ενότητες και τριάντα πέντε δείκτες έχουν οριστεί για να περιγράψουν τους τρεις πυλώνες της βιωσιμότητας σε επτά ευρωπαϊκές αστικές περιοχές, όπως το Bilbao και το Dortmund. Σύμφωνα με τα αποτελέσματα της έρευνας, μόνο η αύξηση του κόστους μετακίνησης με ΙΧ μπορεί να οδηγήσει σε σημαντική μείωση των εκπομπών αερίων του θερμοκηπίου.

Η εξέταση δεικτών βιωσιμότητας των πόλεων αποτελεί σημαντικό εργαλείο για την άσκηση πολιτικής βιώσιμης ανάπτυξης. Οι φορείς της τοπικής αυτοδιοίκησης θα πρέπει να συνδιαλέγονται με τους πολίτες, ώστε να επιτύχουν τους στόχους που έχουν τεθεί. Μια βιώσιμη πόλη θα πρέπει να βελτιώνει συνεχώς τον φυσικό/περιβαλλοντικό σχεδιασμό της σε συνδυασμό με τον οικονομικό της σχεδιασμό. Οι πόλεις που δεν επενδύουν σε αυτό τον τομέα δε θα είναι βιώσιμες και ανταγωνιστικές σε όρους του 21ου αιώνα και θα περιοριστούν οικονομικά.

3. Ευρωπαική πολιτική βιώσιμης αστικής κινητικότητας

3.1 Βιώσιμη Αστική Κινητικότητα: Ευρωπαϊκή Πολιτική & Δράσεις

Η Ευρωπαϊκή Ένωση (Ε.Ε.) συμμετείχε από την αρχή στο διεθνή προβληματισμό για το αστικό περιβάλλον και την αειφόρο ανάπτυξη. Το ενδιαφέρον της Ε.Ε. για τις αστικές περιοχές εμφανίστηκε στο τέλος της δεκαετίας του 1980 και εντάχθηκε στη συνέχεια στο πλαίσιο μιας ευρύτερης συζήτησης για τον ευρωπαϊκό χώρο και τη χωρική ανάπτυξη. Η Ευρωπαϊκή Επιτροπή θέσπισε το 1988 τον «Ευρωπαϊκό Χάρτη για τα Δικαιώματα των Πεζών» ενώ δημοσίευσε το 1990 την Πράσινη Βίβλο για το «Αστικό Περιβάλλον» (Green Paper on the Urban Environment). Η έκθεση αυτή αποτελεί την πρώτη απόπειρα να οριοθετηθεί μια κοινοτική στρατηγική για το αστικό περιβάλλον και την αντιμετώπιση των προβλημάτων της ρύπανσης, του δομημένου περιβάλλοντος και της φύσης και πρασίνου στις πόλεις. Αποτελούσε μια πρώτη προσέγγιση του χώρου και της ταυτότητας της πόλης, υιοθετώντας πρακτικές όπως την ανάμειξη των χρήσεων γης, τις αστικές αναπλάσεις και τη βελτίωση της αρχιτεκτονικής των κτιρίων. Θέτει ως στόχο την επίτευξη ισορροπίας μεταξύ των μέσων μετακίνησης, δημόσιων και ιδιωτικών, υπογραμμίζοντας την ανάγκη περιορισμού του ιδιωτικού αυτοκινήτου για τη βελτίωση της ποιότητας ζωής. Προωθεί την εφαρμογή καλύτερης τεχνολογίας για τη μείωση του θορύβου και των ρύπων των οχημάτων, την ανάπτυξη ηλεκτροκίνητων οχημάτων και τη διευκόλυνση της κίνησης των πεζών.

Η Ευρωπαϊκή Επιτροπή δημοσίευσε το 1995 την Πράσινη Βίβλο «Δίκτυα των Πολιτών» (Green Paper: The citizens network), η οποία εστίαζε στη δημόσια συγκοινωνία και τις συνδυασμένες μεταφορές. Η λειτουργία της πόλης στηρίζεται πλέον σε δίκτυα μέσων μαζικής μεταφοράς και όχι στο αυτοκίνητο. Δίνεται ιδιαίτερη έμφαση στην ενίσχυση των δικτύων κίνησης πεζών και ποδηλάτων, στη μείωση της χρήσης του αυτοκινήτου στις κεντρικές περιοχές και την αξιοποίηση νέων τεχνολογιών όπως της τηλεματικής.

Η Ευρωπαϊκή Επιτροπή εκπόνησε το 1995 την Πράσινη Βίβλο «Για τη Δίκαιη και Αποτελεσματική Κοστολόγηση στις Μεταφορές» (Green Paper: Towards fair and efficient pricing in transport policy). Βασικός στόχος ήταν η προώθηση της βιώσιμης κινητικότητας. Εκτιμήθηκε πως ο δικαιότερος και αποτελεσματικότερος τρόπος ήταν η τιμολόγηση του αυτοκινήτου, καθώς στο κόστος χρήσης του δεν συνεκτιμάται το κόστος κατασκευής και συντήρησης της οδικής υποδομής και οι επιπτώσεις του στο περιβάλλον (φυσικό, τεχνητό και κοινωνικό). Ήταν η πρώτη φορά που στα πλαίσια μιας Πράσινης Βίβλου έγινε αναφορά στα αστικά διόδια.

Η Ευρωπαϊκή Επιτροπή εκπόνησε το 1996 την Πράσινη Βίβλο «Για τη μελλοντική πολιτική για το θόρυβο» (Green paper: Future noise policy). Υποστηρίζει ότι η μείωση του θορύβου και της ατμοσφαιρικής ρύπανσης μπορεί να επιτευχθεί μόνο μέσα από τη μείωση της ταχύτητας και του αριθμού των οχημάτων που κυκλοφορούν στις αστικές περιοχές.

Η Ε.Ε. προχώρησε το 1997 στην εκπόνηση της «Αστικής Ατζέντας» (Towards an urban agenda in the European Union), δίνοντας μια νέα αστική προοπτική στις πολιτικές της και ενισχύοντας την ανταλλαγή εμπειριών μεταξύ των πόλεων. Το 1998, η Ε.Ε. προχώρησε στην εκπόνηση του «Πλαισίου Δράσης για τη Βιώσιμη Αστική Ανάπτυξη», προωθώντας δράσεις όπως η δημιουργία ενός ελκυστικού συστήματος αστικών μεταφορών στα πλαίσια της αειφόρου αστικής ανάπτυξης.

Η Ευρωπαϊκή Οδηγία 96/62/EC για την «Αξιολόγηση και τη Διαχείριση της Ποιότητας του Αέρα» (Air quality, assessment and management), αποτέλεσε ίσως το πιο σημαντικό κείμενο της ευρωπαϊκής πολιτικής στον τομέα της αντιμετώπισης της ρύπανσης του περιβάλλοντος. Εισήγαγε για πρώτη φορά την έννοια των «ορίων ποιότητας», τα οποία είναι χαμηλότερα των συμβατικών ορίων που θεωρείται ότι διασφαλίζουν την υγεία των πολιτών.

Η Ευρωπαϊκή Οδηγία 1999/94/EC για τις «Μεταφορές και το CO_2», έδωσε έμφαση στην υλοποίηση των δεσμεύσεων της Ευρωπαϊκής Ένωσης στη διάσκεψη για το περιβάλλον στο Κιότο το 1997. Στόχος είναι η μείωση των εκπομπών του διοξειδίου του άνθρακα με την εφαρμογή κατάλληλων πολιτικών. Βασική διαπίστωση της Οδηγίας ήταν το πρόβλημα της υπερβολικής χρήσης του ΙΧ και η συνεπαγόμενη αύξηση της εκπομπής διοξειδίου του άνθρακα.

Η Ε.Ε. ανακοίνωσε το 1992 τη Λευκή Βίβλο «Η μελλοντική ανάπτυξη μιας κοινής πολιτικής μεταφορών» (White Paper: The future development of the common transport policy) και το 2001 τη Λευκή Βίβλο «Η ευρωπαϊκή πολιτική μεταφορών το 2010: Η ώρα των αποφάσεων» (White Paper: European transport policy for 2010: time to decide). Στόχος της ήταν η παροχή στους πολίτες ενός επαρκούς και αποτελεσματικού συστήματος μεταφορών το οποίο να:

Προσφέρει ένα υψηλό επίπεδο κινητικότητας σε ανθρώπους και επιχειρήσεις.

Προστατεύει το περιβάλλον, να ενισχύσει την ενεργειακή ασφάλεια, να εξασφαλίζει ελάχιστα επίπεδα εργασίας και να προστατεύσει τους επιβάτες και τους πολίτες.

Αυξάνει την επάρκεια και βιωσιμότητα του διαρκώς αυξανόμενου σε ζήτηση συγκοινωνιακού τομέα.

Στα πλαίσια του 6ου Προγράμματος Δράσης για το Περιβάλλον (6ο ΠΔΠ), με τίτλο «Περιβάλλον 2010: Το μέλλον μας, η επιλογή μας» (2002-2012), στόχος ήταν η «συμβολή σε μια καλύτερη ποιότητα ζωής μέσω μιας ολοκληρωμένης προσέγγισης με επίκεντρο τις αστικές περιοχές και τη διαμόρφωση υψηλού επιπέδου ποιότητας ζωής και κοινωνικής ευημερίας για τους πολίτες, παρέχοντας ένα περιβάλλον στο οποίο το επίπεδο ρύπανσης δεν θα επιφέρει επιβλαβείς επιπτώσεις στην ανθρώπινη υγεία και στο περιβάλλον και ενθαρρύνοντας την αειφόρο αστική ανάπτυξη» (Thematic strategy on the urban environment, 2005). Η ενδιάμεση ανασκόπηση του 6ου ΠΔΠ το 2007, επιβεβαίωσε ότι το Πρόγραμμα παραμένει στη σωστή πορεία στον περιβαλλοντικό τομέα, με στόχο το έτος 2012 (Mid-term review of the sixth Community Environment Action Programme).

Η Ε.Ε. δημοσίευσε το 2007 το «Κεφάλαιο της Λειψίας για τη βιωσιμότητα των ευρωπαϊκών πόλεων» (Leipzig Charter on Sustainable European Cities), το οποίο προωθεί τη δημιουργία ενός υψηλής ποιότητας αστικό περιβάλλον με έμφαση στην αρχιτεκτονική και το περιβάλλον. Ως βιώσιμες κοινωνίες θεωρούνται: «Περιοχές όπου οι πολίτες επιθυμούν να ζήσουν και να εργαστούν, τώρα και στο μέλλον. Ικανοποιούν τις ανάγκες των κατοίκων, είναι ευαίσθητες στο περιβάλλον και συνεισφέρουν σε ένα υψηλότερο επίπεδο ποιότητας ζωής. Είναι ασφαλείς, καλά σχεδιασμένες και δομημένες παρέχοντας ισότητα ευκαιριών και καλές υπηρεσίες για όλους τους πολίτες».

Οι αστικές περιοχές διαδραματίζουν σημαντικό ρόλο στην επίτευξη των στόχων της στρατηγικής της Ε.Ε. για την αειφόρο ανάπτυξη. Στις αστικές περιοχές είναι πολύ πιο έντονες οι περιβαλλοντικές, οικονομικές και κοινωνικές συνιστώσες. Η ελκυστικότητα των ευρωπαϊκών πόλεων θα αναβαθμίσει τις δυνατότητες ανάπτυξης και δημιουργίας θέσεων εργασίας, όντας υψηλής προτεραιότητας για την εφαρμογή της Ατζέντας της Λισαβόνας (Common Actions for Growth and Employment, 2005). Σε υποστήριξη της Στρατηγικής της Λισαβόνας η «Πράσινη Βίβλος για την εδαφική συνοχή» με τίτλο «Μετατροπή της εδαφικής ποικιλομορφίας σε προτέρημα» (Green Paper on Territorial Cohesion, 2008), στοχεύει στη μετατροπή της εδαφικής ποικιλομορφίας σε οδηγό για τη βιώσιμη ανάπτυξη.

Τα περιβαλλοντικά ζητήματα απασχολούν ιδιαίτερα τους ευρωπαίους πολίτες. Σύμφωνα με το Ευρωβαρόμετρο (The attitudes of European citizens towards environment, 2005), το 72% των ευρωπαίων πολιτών θεωρούν ότι οι περιβαλλοντικοί παράγοντες επηρεάζουν είτε «πάρα πολύ» είτε «αρκετά» την ποιότητα ζωής τους.

3.2 Νέα Ευρωπαϊκή Πολιτική: «Προς ένα νέο πολιτισμό για τις αστικές μετακινήσεις»

Η Ε.Ε. προχώρησε στην εκπόνηση της «Ενδιάμεσης ανασκόπησης της Λευκής Βίβλου για τις Μεταφορές 2001» (Mid-term review of the European Commission's 2001 Transport White Paper), ανακοινώνοντας την πρόθεση για τη δημιουργία της «Πράσινης Βίβλου για τις Αστικές Μεταφορές». Η Ευρωπαϊκή Επιτροπή στις 25 Σεπτέμβριου 2007 εξέδωσε τη Νέα Ευρωπαϊκή Πολιτική και συγκεκριμένα την πρόταση για την «Πράσινη Βίβλο: Προς ένα νέο πολιτισμό για τις αστικές μετακινήσεις» (Green Paper: Towards a new culture for urban mobility), με σκοπό μετά από διαβούλευση να διαμορφωθεί ένα «Ευρωπαϊκό Σχέδιο Δράσης για την Αστική Κινητικότητα» που θα πρέπει να ακολουθήσουν τα κράτη μέλη και θα ορίζει χρονοδιαγράμματα εφαρμογής και ανάθεση δραστηριοτήτων. Τα προβλήματα που αντιμετωπίζουν οι πόλεις εξετάζονται ως μέρος μιας ολοκληρωμένης προσέγγισης θέτοντας τους παρακάτω στόχους:

«Προς πόλεις ελεύθερης ροής»

«Προς πιο πράσινες πόλεις»

«Προς πιο έξυπνες αστικές συγκοινωνίες»
«Προσβάσιμες αστικές συγκοινωνίες»
«Προς ασφαλείς αστικές μετακινήσεις»

Οι οριζόντιες δράσεις για την υποστήριξη των προτεινόμενων μέτρων περιλαμβάνουν αλλαγές στο θεσμικό και νομοθετικό πλαίσιο, τη δημιουργία ενός Παρατηρητηρίου Αστικής Κινητικότητας στο πρότυπο του Παρατηρητηρίου Οδικής Ασφάλειας, καθώς και τη συστηματική ενημέρωση, εκπαίδευση και ευαισθητοποίηση των πολιτών. Επίσης, είναι αναγκαία η διερεύνηση των οικονομικών πηγών για την εκπόνηση έργων μέσα από τα διαρθρωτικά ταμεία και το Ταμείο Συνοχής.

3.3 Πράσινη Βίβλος για την Αστική Κινητικότητα

Το επίπεδο συγκοινωνιακής εξυπηρέτησης των περισσότερων ελληνικών πόλεων κινείται σε χαμηλότερα επίπεδα από αρκετές άλλες ευρωπαϊκές πόλεις. Τα κυριότερα προβλήματα που αντιμετωπίζουν οι πολίτες είναι η κυκλοφοριακή συμφόρηση, η έλλειψη πολιτικής στάθμευσης και το χαμηλό επίπεδο εξυπηρέτησης της δημόσιας συγκοινωνίας. Η σημερινή κατάσταση του συστήματος μεταφορών στις ελληνικές πόλεις συσχετίζεται άμεσα με τα χρόνια και πολύπλευρα συμπτώματα μιας πολεοδομικής κρίσης, η οποία εδραίωσε το ρόλο του ΙΧ, προκαλώντας μια στρεβλή ανάπτυξη του συστήματος μεταφορών που με τη σειρά του ευνοεί τις οδικές μεταφορές και τη χρήση ΙΧ οχημάτων.

Η Ελλάδα συμμετείχε στη διαβούλευση της Πράσινης Βίβλου για την Αστική Κινητικότητα. Η προτεινόμενη «Εισήγηση για τη Στρατηγική Αστικής Κινητικότητας» του ΥΠΕΧΩΔΕ (2008) στηρίζεται σε 4 βασικές κατευθύνσεις πολιτικής και για κάθε μια προτάθηκε σειρά μέτρων προτεραιότητας που συνδυάζουν τους καταλληλότερους τρόπους αντιμετώπισης των σύγχρονων ζητημάτων αστικής κινητικότητας των ελληνικών πόλεων. Η εισήγηση αφορά κυρίως πόλεις με πληθυσμό άνω των 10.000 κατοίκων όπου τα κυκλοφοριακά προβλήματα έχουν κάποια κλίμακα, αλλά και σε μικρότερες πόλεις και οικισμούς με εποχιακές κυκλοφοριακές αιχμής λόγω τουρισμού. Τα προτεινόμενα μέτρα προτεραιότητας αφορούν τους ακόλουθους τομείς:

Χωροταξικός, πολεοδομικός και συγκοινωνιακό σχεδιασμός, δίνοντας έμφαση στη συσχέτιση των χρήσεων γης με το σχεδιασμό και τη διαχείριση της συγκοινωνιακής υποδομής, την ιεραρχημένη ανάπτυξη υποδομών, την ιεράρχηση του οδικού δικτύου και την προώθηση θεσμικών ρυθμίσεων για χωροταξικό και πολεοδομικό σχεδιασμό.
Διαχείριση κυκλοφορίας, δίνοντας έμφαση στα μέσα μαζικής μεταφοράς, στην «έξυπνη» κυκλοφορία, την ολοκληρωμένη πολιτική στάθμευσης και τη βελτίωση της οδικής ασφάλειας.

Αναπλάσεις για ήπιες μορφές μετακίνησης, αποδίδοντας ωφέλιμο χώρο στους πεζούς και στους ποδηλάτες εις βάρος της κυκλοφορίας του ΙΧ, μέσω της προσφοράς της κατάλληλης υποδομής, της προώθησης κατάλληλων κυκλοφοριακών ρυθμίσεων.
Τεχνολογίες και μέτρα για το περιβάλλον, όπως τεχνολογίες περιορισμού εκπομπών στα οχήματα, τεχνολογίες περιορισμού εκπομπών στα καύσιμα και περιβαλλοντική τιμολόγηση.

Η αποτελεσματικότητα της στρατηγικής για τη βιώσιμη αστική κινητικότητα βασίζεται στο συνδυασμό των προτεινόμενων μέτρων και όχι την αποσπασματική εφαρμογή τους. Η Στρατηγική Αστικής Κινητικότητας πρέπει να υιοθετηθεί σε όλα τα επίπεδα διακυβέρνησης και φορέων, όπου ο καθένας θα αναλάβει το ρόλο του και καθορίζοντας με σαφήνεια στόχους, που δεν αλληλοαναιρούνται, θα προχωρήσει σε συστηματική εφαρμογή των απαραίτητων μέτρων και δράσεων (Γιαννής, 2003).

4. Στόχοι της Ε.Ε. για τη Βιώσιμη Κινητικότητα

Η Ε.Ε. στοχεύει στη διαβεβαίωση ότι τα συστήματα μεταφορών θα εξυπηρετούν τις οικονομικές, κοινωνικές και περιβαλλοντικές ανάγκες της κοινωνίας και θα περιορίζουν στο ελάχιστο τις αρνητικές τους επιπτώσεις. Σύμφωνα με την Ανανεωμένη στρατηγική (2006), κύριοι στόχοι της ΕΕ είναι οι εξής:

Αποσύνδεση της οικονομικής ανάπτυξης από τη ζήτηση για μεταφορικό έργο με στόχο τον περιορισμό των αρνητικών επιπτώσεων στο περιβάλλον.

Επίτευξη βιώσιμων επιπέδων χρήσης ενέργειας για μεταφορές και μείωση των εκπομπών των ρύπων του θερμοκηπίου.

Περιορισμός των εκπομπών ρύπων από τα μεταφορικά συστήματα με στόχο την ελαχιστοποίηση των επιπτώσεων στην ανθρώπινη υγεία και το περιβάλλον.

Μείωση των επιπέδων θορύβου τόσο με μέτρα στην πηγή όσο και στο οδικό περιβάλλον για τη μείωση των επιπτώσεων στην ανθρώπινη υγεία.

Εκσυγχρονισμός των συστημάτων αστικών μαζικών μεταφορών, ώστε να γίνουν πιο ελκυστικά και αποτελεσματικά μέχρι το 2010.

Βελτίωση της τεχνολογίας των οχημάτων, ώστε να μειώσουν τις εκπομπές CO_2 σε 140g/km (2008/09) και 120g/km (2012).

Μείωση 50% των θανάτων από τροχαία ατυχήματα μεταξύ των ετών 2000 και 2010.

Το έτος 2013 η Ευρωπαϊκή Επιτροπή δημοσίευσε μια έκθεση με τίτλο: «Μαζί για ανταγωνιστική και αποδοτική από άποψη πόρων αστική κινητικότητα». Σύμφωνα με την έκθεση, κεντρικός στόχος ενός σχεδίου βιώσιμης αστικής κινητικότητας είναι η βελτίωση της προσβασιμότητας των αστικών περιοχών και η παροχή υψηλής ποιότητας και βιώσιμης κινητικότητας και μεταφορών, είτε πρόκειται για διέλευση από αστικές περιοχές είτε για μετακίνηση μέσα στις ίδιες τις αστικές περιοχές. Αφορά περισσότερο τις ανάγκες μιας πόλης που λειτουργεί και την μείζονα περιοχή της παρά τη διοικητική περιφέρεια του δήμου.

5. ΣΥΜΠΕΡΑΣΜΑΤΑ

Η ανθρωπότητα διείδε ότι η ασύστολη χρήση φυσικών πόρων οδηγεί σε υποβάθμιση της ποιότητας ζωής των μελλοντικών γενεών. Για το λόγο αυτό μια σειρά από πολιτικές και δράσεις ήρθαν να ενισχύσουν την άποψη ότι και οι μετακινήσεις πρέπει να συμβάλλουν στη δημιουργία ενός μέλλοντος όχι απλά βιώσιμου, αλλά αξιοβίωτου και κοινωνικά ίσου για όλους τους πολίτες. Η Ευρωπαϊκή Ένωση (Ε.Ε.) δραστηριοποιείται εντατικά σε αυτόν τον τομέα με πρωτοβουλίες όπως η «Ευρωπαϊκή Χάρτα για τα Δικαιώματα των Πεζών» (1988), η «Πράσινη Βίβλος για το Αστικό Περιβάλλον» (1990), η Λευκή Βίβλος του 2001 «Η ευρωπαϊκή πολιτική μεταφορών το 2010: Η ώρα των αποφάσεων» που έθεσε τις βάσεις για τη σημερινή πολιτική μεταφορών και η Πράσινη Βίβλος του 2007 «Προς ένα νέο πολιτισμό για τις αστικές μετακινήσεις» που προωθεί τις βιώσιμες αστικές μετακινήσεις. Η Ελλάδα ακολουθεί τα τελευταία χρόνια όλες τις πρωτοβουλίες της Ε.Ε., αν και υπολείπεται αισθητά στις δράσεις της για τη βελτίωση της πεζής κίνησης και της χρήσης του ποδηλάτου.

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Περίληψη
Οι κοινοί πόροι, ή απλά κοινά, αποτελούν μια ειδική κατηγορία φυσικών ή ανθρωπογενών πόρων, οι οποίοι μοιράζονται δύο κύρια χαρακτηριστικά: ανήκουν σε όλους, πράγμα που σημαίνει ότι κανείς δεν μπορεί να αποκλειστεί από τη χρήση τους, ενώ την ίδια στιγμή, η χρήση τους από κάποιον μειώνει τη διαθέσιμη ποσότητα για τους υπολοίπους. Για τους λόγους αυτούς, συχνά αντιμετωπίζουν τον κίνδυνο υπερεκμετάλλευσης, υποβάθμισης ή ακόμη και καταστροφής τους, τη λεγόμενη «τραγωδία των κοινών». Ένα τυπικό παράδειγμα «τραγωδίας» αποτελούν τα υπόγεια ύδατα, των οποίων η αποτελεσματική διαχείριση θα μπορούσε να οδηγήσει στην οικονομική ανάπτυξη και στην ευημερία. Βασιζόμενη στο πλαίσιο ανάλυσης των κοινών πόρων, όπως αναπτύχθηκε από την βραβευμένη με Νόμπελ το 2009 Elinor Ostrom, η συγκεκριμένη μελέτη διερευνά το ζήτημα της συλλογικής διαχείρισης των υπόγειων υδάτων χρησιμοποιώντας ως μελέτη περίπτωσης την περιοχή της Λάρισας, μία από τις σημαντικότερες γεωργικές περιοχές αλλά και έναν από τους μεγαλύτερους υδροφόρους ορίζοντες της Ελλάδας. Συγκεκριμένα, η εργασία αναπτύσσει το εννοιολογικό πλαίσιο για την μελέτη των υπογείων υδάτων ως κοινών πόρων και αξιολογεί εμπειρικά τη δυνατότητα συλλογικής δράσης των χρηστών που χρησιμοποιούν τα υπόγεια ύδατα για αρδευτικούς σκοπούς. Αυτό γίνεται μέσα από μια έρευνα, η οποία διερευνά τις απόψεις κατοίκων και τοπικών φορέων σχετικά με την ένταση του προβλήματος του νερού (από την άποψη τόσο της ποσότητας όσο και της ποιότητας), τις πρακτικές άρδευσης και του βαθμού εξάρτησης των αγροτών από τον πόρο, και της ύπαρξης κοινωνικών σχέσεων μεταξύ των χρηστών, οι οποίες θεωρούνται απαραίτητες για την ανάπτυξη επιτυχημένων, αυτο-οργανωμένων και μακράς διάρκειας λύσεων. Η έρευνα δείχνει ότι οι αγρότες παρουσιάζονται επιφυλακτικοί ως προς τη δυνατότητα αυτο-διαχείρισης των υπόγειων υδάτων, πράγμα που οφείλεται στην έλλειψη εμπιστοσύνης τόσο μεταξύ τους και προς τους άλλους φορείς του αγροτικού τομέα.

Λέξεις-κλειδιά: Διαχείριση των υπόγειων υδάτων, κοινοί πόροι, τραγωδία των κοινών, Λάρισα.
JEL κωδικοί: A13, B52, D02, D70, P48, Q01, Q15, Q25, Q50, R11

From tragedy to opportunity?
Groundwater as commons in Larisa region

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Abstract
The commons are natural or manmade resources that due to non-excludability and subtractability face serious risks of overexploitation, mismanagement or even

destruction, the so-called "tragedy of the commons". Groundwater is a typical example of such a resource. Drawing on the framework developed by the 2009 Nobel laureate Elinor Ostrom, this research explores issues of collective management of groundwater using Larissa area, one of the most important agricultural areas of Greece, as a case study. More specifically, the paper assesses empirically the possibility of user-based management of groundwater used for irrigation purposes. This is done through a survey which explores, *inter alia*, the views of local stakeholders on the intensity of the water problem, the irrigation practices and the existence of trust-based social relations between the farmers, which are seen as essential for the development of successful, long-enduring, user-governance solutions. The research finds that farmers are rather reserved towards the possibility of groundwater self-management, which may be due to lack of trust both among them and towards the other players in the field. On these grounds it seems that the most appropriate solution would be to create an independent management authority with multiple responsibilities and powers.

Keywords: Groundwater; common pool resources; tragedy of the common; Larisa.

JEL codes: A13; B52; D02; D70; P48; Q01; Q15 ; Q25 ; Q50 ; R11.

1. Introduction

The commons, or, more properly, common pool resources (CPRs), is a special category of resource characterised by non-excludability, meaning that it is too difficult (i.e. too costly) to excluded someone from using them, and subtractability, meaning that use by someone reduces the amount of the resource available to others. These features of commons enable rational individual s (acting in their immediate self-interest) to use as much of the resource as they like, without taking full responsibility for their actions. As a result, the resource is gradually depleted and eventually led to degradation and destruction, a situation known as the “tragedy of the commons” (Hardin, 1968).

The “tragedy” is due to two reasons. On the one hand it is the result of the economic rationally behaviour of the users (which seek to maximize their individual immediate benefit, disregarding the social/collective long-term costs of their actions), and on the other, this becomes possible because there is a lack of a proper institutional framework to safeguard sustainable management of the resource, that is a framework to credibly define, allocate and enforce property rights to the actors involved. On these grounds, possible solutions to the commons’ tragedy could be to infuse stewardship ethic among users (Worrell and Appleby, 2000; Barclay, 2004), and/or, as Hardin (1968) and others (e.g. Libecap, 2009) have argued, to attribute clearly defined property rights, either to individuals (privatization) or to the state (nationalization), giving the owner the incentives and authority to enforce the sustainability of the resource.

However, the 2009 Nobel laureate in Economics, Elinor Ostrom, has revisited Hardin’s work and drawing on a number of empirical studies across the world demonstrated that communities can successfully manage commons even in the absence of private property rights and a strong external regulatory authority. In particular, Ostrom (1992, 1999, 2008, 2010) made clear that local users are able to overcome collective action problems and to develop indigenous, self-organised and long-enduring institutions for the sustainable management of the CPRs. These institutions are particular social arrangements (rules, norms, routines, customs, etc.) which define and allocate rights and obligations among users and provide the mechanisms for policing and enforcing them.

Combining field and experimental research on the commons, Ostrom and other scholars (Wade, 1987; Agrawal, 2003) identified a number of characteristics that are common to all successful management structures. These can be organised under five headings. The first group of elements regards the resource itself; resources of smaller sizes with definable boundaries, for example, can be preserved much more easily. A second group concerns the characteristics of the user community; small and homogeneous populations with a thick social network based on trust, with experience in self-regulation and with social values promoting conservation (e.g. stewardship ethic) do better. The third group of conditions has to do with users' dependence on the resource; there must be a perceptible threat of resource depletion, and the community (current and future generations) should depend to a high degree on the resource for its living. The fourth group refers to the governance structure, that is, the institutional arrangements that should be developed to manage the CPR; locally-emerged, used-based, simple rules with simple, internal and low-cost policing and enforcement procedures are preferable. Finally the last group concerns the external environment; clear and supportive state regulations (with formal incentives and sanctions) and accommodating and collaborative local/regional authorities do help to a great extent.

Groundwater constitutes a typical example of CPRs (Theesfeld, 2010). It is subject to rivalry in consumption in the sense that there is a finite amount available, which must be shared over a variety of users/uses and geographical areas. In addition, the change of the climate of the planet, with the rise of the world temperatures and the reduction of the annual rainfalls, and the increase of the environmental degradation and the water demand (for agricultural, industrial and residential uses), has made groundwater a valuable resource in scarcity (Mariolakos, 2007). In this sense, politicians, academics and journalists alike have often argued that disputes over freshwater would be the source of conflicts and wars in the near future. So, the 'tragedy' might be even worse.

Drawing on the analytical framework of commons developed by Ostrom, this research explores issues of collective management of the groundwater resource using Larissa area, one of the most important agricultural areas of Greece, as a case study. In particular the paper explores empirically the possibility of user-based management of groundwater used for irrigation purposes. This is done through a survey which sets out the views of local farmers on the intensity of the water problem (in terms of both quantity and quality), their irrigation practices and degree of their dependence on the resource, and the existence of trust-based social relations between the users, which, as mentioned, are seen as essential for the development of successful, long-enduring, community-based governance solutions.

The paper is structured as follows. The following section assesses the formal regulatory framework that prescribes (ground)water usage in Greece, whereas the next one moves to outline the condition of water resources in Thessaly, which is the region where Larisa is located. Section four presents the analysis and results of the case study, and section five concludes.

2. The Legal Framework of Water Management

As discussed, facilitative to sustainable CPR management is the provision of a formal institutional (legal) framework that clearly and credibly defines (property) rights and responsibilities and enforces compliance to those involved, providing incentives for proper consumption, management and conservation of the resource.

As far as Greece is concerned, the Framework Laws 1650/1986, for the 'Protection of the Environment', and 1739/1987, for the 'Management of Water Resources', constituted the first substantial attempts towards the provision of an integrated legal frame able to support sustainable water management (Kampa and Bressers, 2008). Although they were only partially implemented, mainly due to public sector inability to put into effect some of their provisions, they endowed relevant parties with the necessary experience that made possible the next round of institutional development, which was the transposition of Water Framework Directive 2000/60/EC into the Greek national legal system.

The Water Framework Directive (WFD) provided the frame of water policy for all EU member states aiming to ensure good status of all water bodies by 2015. To do so it established a number of common objectives, principles, definitions and measures for the sustainable management of the water resources, and prescribed the steps that member states need to follow in order to reach the common goal, taking in due account not only environmental but also economic and social considerations.

Despite the shortcomings of the WFD (Baltas and Mimikou, 2006) Greece has been relatively prompt in incorporating it into the national legal context through the adoption of the 3199/2003 'Water Protection and Management' Framework Law (Kanakoudis and Tsitsifli, 2010). This Law introduced most of the new definitions and notions of the Directive and determined the competent authorities and the analytical procedures that they should follow for each individual issue, but did not go through a number of important provisions specified by the WFD (left to be regulated in future time). This partial harmonization with the Directive brought Greece to the European Court of Justice for a couple of times, until the 51/2007 Presidential Decree came up which literally transposed (word-by-word) all the provisions left out from the Framework Law. This delay in transposition, however, has brought further delays to a number of implementation actions (Sofios et al., 2008), posing a serious threat to the overall process. In addition the recent financial crisis that afflicted the country with the hard austerity measures that imposed to local bodies has put into question the financial feasibility and necessity of the program, and made its requirements to be somewhat neglected (Kalampouka et al., 2011). This, nevertheless, brought new impetus to bottom-up, user-based initiatives aiming to manage the water resource in a sustainable way (defined here as commons).

3. The Characteristics of Water Resources

The Thessaly Water District (WD) virtually coincides with the corresponding regional territory incorporating almost the whole prefecture of Larisa and large parts of the prefectures of Magnesia, Trikala and Karditsa. Its total area is 13,136 sq km (with population in 2011 of 746,714 residents), which is divided in three sections: the eastern costal and mountainous area, the central flat area, and the western mountainous area. The Thessaly WD comprises the basins of Pineios river (and its tributaries) and the lake of Karla, as well as two self-contained aquifers, the western and the eastern, covering 4,520 sq km, or 35% of the region's area. The rainy season lasts from October to January and the dry one from July and August, giving an average annual precipitation of about 678 mm, which is one of the lowest in the country (WMC, 2005). This provides a first indication of the water condition that the area exhibits.

Extended to an area of 14,000 sq km (about 11% of the whole country), the Thessaly region incorporates the highly fertile plain of Larisa, providing the 14.2% of the national agricultural product (40% of cotton) and making it one of the most important agricultural areas of Greece. Agriculture is the main consumer of Thessaly's water resources (87% of the total demand). The 2,500 sq km of irrigated farmland require about 1,550 million m^3 of water annually, whereas the sustainable supply is about 750 million m^3 (or which the 550 are groundwater) (Goumas, 2006). This gives an annual deficit of roughly 800 million m^3 of water (the highest in the country), which is usually extracted through illegal bore-wells (count to be more than 30,000, according to some unofficial estimates) depleting the groundwater resource and leading to 'tragedy'.

The dropping levels of the water table of the eastern aquifer, where our case study is located, provide another indication of the extent of the problem. According to Goumas (2006), from 1985 onwards there has been a steady decrease of the groundwater level, dropped by 50% in 2005. In addition to the quantitative depletion of the resource, there is also qualitative deterioration, which comes from two main sources (Polyzos et al., 2006). First is saltwater intrusion (since the area is close to the coast and there is a hydraulic connection between the two bodies), and second is nitrate pollution due to crop over-fertilization (as a result of lack of both proper education of the farmers and supervision by the regulatory authorities) both of which cause contamination to the groundwater, with catastrophic consequences for the agriculture and the economy of the area.

4. Is the Tragedy of the Commons Unavoidable?

4.1. Research Concept and Methodology

Previous sections made evident the extent of the groundwater degradation in Larisa (mainly due to illegal water extraction) leading to a tragedy of the commons, and the deficiencies of the formal-legal framework to deal effectively with all these issues. The current section investigates the possibility of developing some bottom-up, user-based initiatives towards the sustainable management of the CPR. This is done through a questionnaire survey which explored the views and attitudes of local farmers on a number of relevant issues, such as the condition of the resource and the factors affecting this, the degree of their dependence on the resource, the strength of their social relations and the level of trust between them, and the institutional arrangements which they deem necessary towards sustainability.

The people surveyed constitute the local farmers (users) of the area of Platykampos (a municipality located at about 10 km south-east of the Larisa city). Survey questions were pre-tested in a pilot study enabling fine-tuning of the instrument and improvement of its clarity. The final questionnaire consists of six parts containing thirty-five questions of all types: measurement, dichotomous, ordinal, as well as Likert-scale and semantic-differential ones scaled from 0 (denoting strong disagreement, negative opinion, etc.) to 10 (denoting strong agreement, positive opinion, etc.). The first part informs the respondent on the purpose of the research and ensures the anonymity of participation. The second part records views regarding the adequacy and quality of the groundwater (at present and in the near future), and the factors that affect its condition. The third part contains questions about the farming practices and water consumption. The fourth part assesses which institutional arrangements are conductive to sustainable water management. The final part of the questionnaire gathers information about the respondents, such as age, gender and education.

The survey was held during the first quarter of 2010. Questionnaires were distributed in person and asked to complete on the spot. Questionnaires were validated, and then coded and analysed to generate a number of statistics illustrating the respondents' views on the issues.

4.2. Response Rate and Composition of Respondents

A total of 200 distributed questionnaires yielded 133 properly completed responses (a response rate of 66.5%). The respondents were principally men (89.5%), reflecting male dominance in the agricultural sector (see Table 1). The 30-50 age bracket was the main group (51.8%), followed by those over fifty (47%) and those below thirty (1.2%). The average age of the sample was about fifty-year-old. Most respondents (51.2%) have completed high school, whereas 30.1% have some further education. The 70% of the farmers had acquired only compulsory education.

Table 1: Composition of respondents

			M	*SD*	*Mdn*
Gender	Male	89.5%			
	Female	13.4%			
Age	<30	1.2%	49.7	11.1	50
	30-50	51.8%			
	>50	47.0%			
Education	Primary or less	18.8%			
	Secondary	51.2%			
	Post-secondary	11.3%			
	Tertiary (university)	15.0%			
	Postgrad	3.8%			

4.3. The Condition of Groundwater

When asked to assess the adequacy of groundwater for irrigation purposes respondents almost unanimously acknowledged the problem (see Table 2). The majority of the sample (31.1%) replied that there is a water shortage - average score of 2.6. Similar, if not gloomier, was their response regarding the situation over the next decade. More than 75% of the people said that *ceteris paribus* the resource will diminish, whereas most respondents (28%) gave the lowest score - zero (average score 1.3). Interestingly, a 3% of the sample replied that there will be some increase in the groundwater reserves. In line was the next question, asking whether the resource faces a tragedy condition. Over 80% of the respondents agreed that the amount of water extracted is not replenished, whereas more than 50% gave the highest scores (indicating the severity of the problem).

Turning to the factors that held responsible for this situation, out of the five put forward, the bad management scored higher (mean of 7.6, with more than 25% of respondents giving the highest score), followed by climate change (mean 6.3) and by agricultural consumption and wasteful use (both scored 6.1). When asked to assess the percentage of illegally extracted water, they indicated on average that this should be the

32.1% of that totally consumed. Similarly, they deemed that only 16.3% of the users extract water illegally.

Table 2: Perceptions on the condition of groundwater

		0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	6 (%)	7 (%)	8 (%)	9 (%)	10 (%)	N	M	SD	Mdn	Percentiles		
																	25	50	75
Groundwater condition	Water adequacy (0: shortage, 10: abundance)	10.4	20.7	31.1	18.3	5.5	3.0	3.7	1.8	4.3	1.2	0	133	2.6	2.0	2	1	2	3
	Quantity in next decade (0: deteriorate, 10: improve)	28.0	23.2	25.6	7.9	7.9	4.3	0.6	1.8	0.3	0.3	0.0	133	1.3	1.6	1	0	1	2
	“Tragedy of the commons” (0: disagree, 10: agree)	3.7	0.6	2.4	1.2	3.7	3.7	3.7	11.0	18.3	23	28.7	133	7.8	2.5	9	7	9	10
Factors affecting groundwater (0: not important, 10: very important)	Climate change	2.4	3	6.7	5.5	3.7	11.6	14.6	18.3	14.6	3.0	16.5	133	6.3	2.6	7	5	7	8
	Agricultural consumption	5.5	1.2	3.7	4.3	7.9	13.4	12.2	19.5	17.1	6.7	8.5	133	6.1	2.6	7	5	7	8
	Nonagricultural consump.	3.0	9.8	8.5	25.0	14.0	17.1	14.6	3.7	1.8	0.6	1.8	133	4.0	2.0	4	3	4	5
	Wasteful use	7.9	1.8	4.3	6.1	7.9	10.4	8.5	15.2	15.9	8.5	13.4	133	6.1	3.0	7	4	7	8
	Bad management	1.2	0.6	1.8	1.2	3.7	11.0	8.5	10.4	17.1	18.9	25.6	133	7.6	2.3	8	6	8	10

4.4. Irrigation Practices and Attitudes

As regards irrigation practices, the vast majority of the farmers (76.7%) admit that they use as much water as there is available, with aim to maximise crop production. After all, they confess, even if they do not do so, someone else will. Of the rest 23.3% that cares for water conservation, the 22.5% does this due to concerns of water availability in the future, and only a 0.8% act on purely altruistic motives (that is, for water to be available to the others). Overall, it becomes evident that utility maximization drives to a large extent farmers’ behavior, which, due to non-excludability, gives rise to a free-rider situation.

The above finds also support on the next question asking whether farmers would be willing to slim down their water extraction levels as part of a maintenance program. Interestingly, 29.3% of the respondents have a rather opposing stance, and of the rest which agrees to do so, the 39.8% seems willing only if economic incentives are given, whereas the 20.3% if there would be additional measures for compliance by all users.

4.6. Groundwater as Commons

The current section explores the need for, previous experience of, and willingness of farmers to be engaged in some form of user-based initiatives towards groundwater sustainable management. The specific issues examined are the degree of user dependence on the resource, the preferred allocation of ownership rights on groundwater, the kind of institutional arrangements regarded as conductive to sustainable management, the strength of trust-based social relations among users, and their past experience and willingness to cooperate with each other towards the aforementioned end.

Three questions were set to assess the degree of user dependence on groundwater and on agriculture in general. First, farmers were asked to estimate the change in their crop production capacity and resulted income if there was no groundwater available. Though replies were varied considerably, on average a 71.1% reduction in production and a 67.9% reduction of incomes were reported. The second question explored whether farmers would consider changing their occupation. Though 26.4% of respondents was rather negative, the majority (46.7%) was quite positive (and the rest was indecisive) (see Table 3). To assess long-term inter-generational dependence, farmers were next asked whether they believe their offsprings would take over their family business. The results were overwhelming: the 57.2% of respondents deemed that their children will not continue farming, 20.4% was not sure, and 22.6% thought that rather they will. Overall, it became evident that although farmers and their families depend highly on groundwater for their living, this situation could be rather impermanent and short-termed. On these grounds it is doubtful whether they would be willing to engage themselves and invest in longstanding relations regarding the management and maintenance of the resource.

Table 3: Farmer dependence on groundwater

	0 (%)	*1 (%)*	*2 (%)*	*3 (%)*	*4 (%)*	*5 (%)*	*6 (%)*	*7 (%)*	*8 (%)*	*9 (%)*	*10 (%)*	*N*	*M*	*SD*	*Mdn*	*Percentiles*		
																25	*50*	*75*
Occupation change	21.1	3.0	2.3	3.8	5.3	12.0	6.0	7.5	9.8	2.3	27.1	133	5.6	3.8	6	2	6	10
Offsprings continue farming	39.8	5.3	8.3	3.8	3.8	12.8	3.8	6.8	3.8	1.5	10.5	133	3.3	3.5	2	0	2	6

The above findings explain relatively well the assignment of property rights that stakeholders seem to prefer, which is examined next. In particular, respondents were asked to choose who should have the ownership of groundwater in order sustainability to be achieved: the central or local government (i.e. nationalization), a specialized management organization, formal associations/cooperatives of farmers, all farmers collectively, each farmer individually, private investors (i.e. privatization), or none of the above? Here farmers showed a degree of divergence. Not unexpectedly (given the results on trust, discussed below), almost half of the respondents (49.1%) opted for the specialized management organization, the 20.5% upheld the central state, the 13.7% argued for ownership to be split between farmers, and only the 11.0% endorsed a form of user-based ownership (that is, 5.5% voted for farmer associations and 5.5% for collective ownership). Interestingly, a tiny 1.7% chose privatization (i.e. ownership by private investors) as the preferable solution. Generally the results indicated that neither privatization nor any form of community ownership were deemed capable to ensure proper use and longevity of the resource.

Next, respondents were asked to assess a number of institutional arrangements in terms of their significance for sustainable management (Table 4). With mean value of 8.0 first scored ‘rule enforcement’, which, as seen, is the major deficiency of the Greek institutional framework. Next came the ‘specification of rules for use’, the ‘specification of sanctions for violations’ and the ‘monitoring of rule compliance’ (7.8). Last were placed arrangements regarding the ‘precise specification of users’ (6.8), ‘user coordination and conflict management’ (6.7) and ‘user participation in management’ (6.7).

The next set of two questions attempted to assess the strength of trust-based relations of users (a form of social capital). First, the trusting attitude of farmers was measured using a semantic-differential question with the following contrasting options: “I do not trust someone until there is clear evidence that (s)he can be trusted” indicating low trusting behavior (scored 0), and “I trust someone until there is clear evidence that (s)he cannot be trusted” indicating high trusting behavior (scored 10). Table 5 presents the results making apparent the low degree of trusting that characterizes farmers in Larisa. In particular, the 58% of respondents described themselves as rather reserved and suspicious (interestingly, 36.1% picked the lowest scope), the 13.6% placed themselves on the middle of the scale, and a low 28.7% put themselves on the high end of the trusting spectrum. Since interpersonal trust is a relative concept, depending on who it is directed at, the next question tried to assess the degree of trust farmer have on various people/entities: relatives, friends, fellow-villages, other farmers, farmer associations/cooperatives, technocrats/scientists, specialised bodies, local authorities, and the central state.

As Table 5 reveals, friends is the most trustworthy group (mean of 6.6), followed by technocrats (6.5) and relatives (6.0). Respondents were reserved against farmer associations (mean score of 5.6) and specialised bodies (4.9), and they distrusted local authorities (score of 3.8), other farmers (3.7), fellow-villagers (3.5) and the central state, which got the lowest score (3.0).

Finally, it has been examined whether farmers had previous cooperative experience and how willing they would be to cooperate with others towards groundwater self-governance. As regards the former, the majority of respondents (69.2%) reported that they do participate in associations, cooperatives, clubs, etc. Of them, the 46.2% take part in one such organization, the 37.4% in two, and the rest in thee of more, with average experience greater than twenty years of involvement. As concerns their attitude towards cooperation for self-governance of the commons, the 59.3% of the farmers was rather positive to work with farmers that they know quite well (whereas the 24.1% was reserved), the 63.9% was positive to join forces with organized groups (associations, cooperatives, etc.) of farmers (whereas the 21.1% was sceptical), but only the 15.9% was happy to work together with all interested farmers, in contrast to the 58.6% which was unwilling (see Table 6), indicating, one more time, the low level of trust among farmers in general.

Table 4: Institutional arrangement significance

	0 (%)	*1 (%)*	*2 (%)*	*3 (%)*	*4 (%)*	*5 (%)*	*6 (%)*	*7 (%)*	*8 (%)*	*9 (%)*	*10 (%)*	*N*	*M*	*SD*	*Mdn*	*Percentiles*		
	0: not important										*10: very important*					*25*	*50*	*75*
Specification of users	7.0	1.3	5.0	4.4	1.9	7.6	4.4	15.2	19.0	13.9	20.3	133	6.8	3.0	8	5	8	9
Specification of rules for use	3.8	0	2.5	1.3	1.9	7.0	6.3	12.7	12.7	17	34.8	133	7.8	2.6	9	7	9	10
Specification of sanctions for violations	2.5	1.3	0.6	3.2	2.5	7.0	7.6	10.8	14.6	13.9	36	133	7.8	2.5	8.5	6.8	8.5	10
Monitoring of rule compliance	3.8	1.9	1.9	1.9	1.3	5.0	5.7	9.5	20.9	13.3	34.8	133	7.8	2.6	8	7	8	10
Rule enforcement	1.3	0.6	3.8	1.3	2.5	4.4	4.4	10.8	18.4	15.8	36.7	133	8.0	2.4	9	7	9	10
User coordination & conflict management	6.3	0	3.2	2.5	3.2	11.4	10.1	17.1	22.8	6.3	17.1	133	6.7	2.7	7	5	7	8
User participation in management	8.9	0.6	2.5	3.2	1.3	12.7	11.4	12.0	14.6	10.0	22.8	133	6.7	3.0	7	5	7	9

Table 5: Strength of social relations and trust

		0 (%)	*1 (%)*	*2 (%)*	*3 (%)*	*4 (%)*	*5 (%)*	*6 (%)*	*7 (%)*	*8 (%)*	*9 (%)*	*10 (%)*	*N*	*M*	*SD*	*Mdn*	*Percentiles*		
		0: not trust										*10: trust*					*25*	*50*	*75*
Trusting attitude		36.1	5.3	12.8	3.8	2.3	6.8	4.5	9.8	6.8	3.8	8.3	133	3.5	3.6	2	0	2	7
Trust on	Relatives	6.1	1.5	2.3	6.9	6.1	18.3	9.9	16.0	16.0	9.2	7.6	131	6.0	2.6	6	5	6	8
	Friends	2.3	2.3	2.3	6.1	3.8	11.5	14.5	14.5	18.3	13.0	11.5	131	6.6	2.5	7	5	7	8
	Fellow-villagers	14.5	12.2	13.7	11.5	7.6	13.7	12.2	11.5	2.3	0.8	0	131	3.5	2.5	3	1	3	6
	Other farmers	10.7	7.6	17.6	9.9	14.5	18.3	15.3	2.3	0.8	0.8	2.3	131	3.7	2.3	4	2	4	5
	Farmer associations	5.3	3.1	6.1	6.1	11.5	15.3	12.2	12.2	15.3	3.1	9.9	131	5.6	2.7	6	4	6	8
	Technocrats/scientists	8.4	0.8	0.8	5.3	2.3	13.0	10.7	14.5	19.8	13.7	10.7	131	6.5	2.8	7	5	7	8
	Specialised bodies	11.5	4.6	5.3	6.1	9.9	16.8	12.2	16.0	12.2	2.3	3.1	131	4.9	2.7	5	3	5	7
	Local authorities	13.7	8.4	10.7	16.8	11.5	12.2	10.7	8.4	3.8	2.3	1.5	131	3.8	2.6	4	2	4	6
	Central state	24.4	11.5	11.5	15.3	8.4	9.9	6.9	4.6	4.6	0.8	2.3	131	3.0	2.7	3	1	3	5

Table 6: Attitude towards self-governance of the groundwater as commons

	0 (%)	*1 (%)*	*2 (%)*	*3 (%)*	*4 (%)*	*5 (%)*	*6 (%)*	*7 (%)*	*8 (%)*	*9 (%)*	*10 (%)*	*N*	*M*	*SD*	*Mdn*	*Percentiles*		
Cooperation with:	*0: no*										*10: yes*					*25*	*50*	*75*
...farmers I know well	15.8	1.5	3.0	3.8	1.5	9.8	5.3	10.5	12.0	7.5	29.3	133	6.4	3.6	7	4	7	10
...organized farmer groups	15.8	3.0	0	2.3	3.0	3.0	9.0	4.5	14.3	17.3	27.8	133	6.7	3.6	8	5	8	10
...all farmers	35.3	9.8	7.5	6.0	8.3	7.5	9.8	5.3	5.3	1.5	3.8	133	3.0	3.1	2	0	2	6

5. Conclusions

Groundwater as a typical example of a common pool resource is subject to serious risk of overexploitation, pollution, degradation (in terms of both quantity and quality) and even total destruction (the so-called ‘tragedy of the commons’). The conventional literature prescribed either privatization or full nationalization of the resource as appropriate solutions to the problem. However, many countries in the world (including Greece) exhibit a number of characteristics (such as, weak property rights, deficient policing and enforcement mechanisms, rigid and bureaucratic institutions, etc.) which preclude successful implementation of such top-down approaches. In turn, as the 2009 Nobel laureate in economics Elinor Ostrom has established, the users themselves can develop collective institutional arrangements that provide solutions to the commons problem which are more socially acceptable, more durable and sustainable, and with lower implementation costs.

Drawing on the analytical framework that Ostrom and other scholars on commons have developed, the current paper has examined issues of collective management of the groundwater resource using Larisa area (one of the most important agricultural regions in Greece) as a case study. Issues examined include the overall institutional/legal framework available for groundwater management, the irrigation practices in the area, the condition of Larisa’s groundwater (and the perception farmers have about it), the institutional and other arrangements that local users deem as significant for the maintenance of the resource, and the capability of farmers to join forces towards the self-governance of commons. A number of points have emerged.

First, adverse climate conditions, poor resource management and overexploitation practices (such as illegal water extraction) have over the years depleted and downgraded the groundwater resource of Larisa, putting into great danger the agriculture industry and the whole economy of the region. Second, despite significant legal developments undertaken under the WFD, the existing regulatory framework lags behind in terms of

ability to deal effectively with the tragedy condition that the groundwater of the area faces. Third, farmers (and users in general) are fully aware of the severity of the problem, but deficient policing and enforcement mechanisms on the part of the state, and opportunistic, free-riding behaviour on the part of the farmers (fed by the low intergenerational dependence on the resource and the subsequent short-term exploitation horizon) have intensified the condition and precluded the exploration of more innovative solutions to the case. Fourth, an additional and serious obstacle towards the development of community-emerged user-based governance arrangements has been the lack of trust both among farmers and between farmers and other interested parties (which in a sense constitutes a social capital deficit), putting into doubt whether user participation can indeed be part of successful solutions. Fifth, given the reluctance of the farmers to engage themselves and invest in longstanding relations regarding the management and maintenance of the resource, the most pragmatic solution would be the development of an independent management authority with multiple responsibilities and powers.

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A multilevel analysis of the determinants of individual well-being in European countries

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Abtsract
The aim of this study is to examine the effects of individual and macroeconomic factors upon various facets of individual subjective well-being. The study draws data from the Eurobarometer survey that was carried in 2011 in a large sample of European countries. Under the light of the adverse economic conditions prevailing in 2011 in many European countries, the study concentrates on the effects of individual perceived employability conditions and job insecurity feelings and their effect upon individual well-being facets. A multilevel modeling approach is adopted in order to examine the hypothesis that the observed effects of job characteristics may differ when national macroeconomic conditions are worse. In detail, the multilevel modeling allows us to assess the relative importance of the national and individual characteristics upon well-being facets. A wide range of personal demographic, economic and work characteristics are examined at the individual level. National macroeconomic (such as the Gini income inequality index and labour market protection measures) and environmental (environmental protection index) factors are also examined at the national level.

Keywords: Well-being; job security; European countries.
JEL classification: J28; J08; C21.

1. Introduction

The past few decades, economists have increasingly placed attention in quantifying the wellbeing of the populations (Van Praag and Ferrer-i-Carbonell, 2010). Following the seminal work of Easterlin (1974), a growing interest is observed among economists to examine the effects of socio-economic variables upon wellbeing (Pittau et al., 2010). Measures that are based on direct individual assessments of overall and domain satisfaction, happiness and the like are widely used in economics research and they have been found to be strong predictors of subsequent individual outcomes such as job quits, productivity and the like (Clark, 2001; Van Praag and Ferrer-i-Carbonell, 2010).

At the same time, it is important to understand the driving forces of individual wellbeing. The majority of studies can be roughly categorized in two areas, namely those examining the determinants of wellbeing at the individual level and those that proceed in cross-country comparisons and examine the effect of macroeconomic characteristics upon wellbeing as well (Bjørnskov et al., 2008; Pierewan and Tampubolon, 2014). Still, the increasing attention that the literature on wellbeing has received due to the policy implications it entails, motivates researchers to produce valid and robust findings (Bjørnskov et al., 2008). Bjørnskov et al. (2008) stresses the need to appropriate accommodate the impact of macroeconomic factors such as economic variables, political and institutional characteristics on wellbeing models at the individual level.

This study focuses on the effects of labour market characteristics upon overall wellbeing and domain wellbeing (namely, satisfaction with work). Of special interest are the effects of *job security* feelings and *perceived employability* conditions upon individual satisfaction. By using recent data from 2011, is expected that adverse labour market conditions have affected negatively individual perceptions about national labour market setting and they have led to increased feelings of job insecurity and increased concern about future prospects (Wittekind et al., 2010). While the two indicators of *job security* and *perceived employability* are strongly related they do differ in the sense that job security is related to the concerns about the current job the individual holds, while perceived employability is regarding alternative labour market opportunities the individual faces in case of job loss (Wittekind et al., 2010). Both are also found to be strong determinants of not only individual wellbeing but of job performance, productivity, intention to quit and absenteeism rates (Wittekind et al., 2010).

The structure of the paper is as follows: the section that follows presents a description of the variables used and the methodology adopted. The third and last section discusses the findings and concludes.

2. Variables and Methodology

This study examines the impact of individual and macroeconomic characteristics upon two indices of individual wellbeing, namely life satisfaction and satisfaction with work. The dataset is drawn from the Eurobarometer Study that organized and monitored by the European Commission, during September and November 2011. The dataset covers a wide range of information concerning individual demographic, social and economic characteristics. The countries utilized in the study are 27, in detail: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the UK. The remaining countries (Croatia, Iceland, Norway and Turkey) which participate in the Eurobarometer survey are excluded from the analysis due to missing information in the main variables of interest.

Since we are interested in the microeconomic and macroeconomic determinants of individual wellbeing, two indicators that are mainly applied in the happiness economics area are utilized, namely overall satisfaction and satisfaction with work (Van Praag and Ferrer-i-Carbonell, 2008, 2010). The overall satisfaction index is derived from the question:

Could you please tell me on a scale of 1 to 10 how satisfied you are with your life in general, where '1' means you are "very dissatisfied" and '10' means you are "very satisfied"?

The domain satisfaction index regarding satisfaction from work is drawn from the following question:

Could you please tell me on a scale of 1 to 10 how satisfied you are with your work, where '1' means you are "very dissatisfied" and '10' means you are "very satisfied"?

The two main independent variables of interest that are utilized in the study are related to the individual assessment of *job security* feelings and *perceived employability* conditions that are considered to be strong determinants of individual wellbeing (Geishecker, 2009; Wittekind et al., 2010). The former, namely job security is assessed from the following question:

How confident would you say you are that you will keep your job in the coming months? Are you…Not very confident / Not at all confident / Very confident / Fairly confident

Whereas the perceived employability conditions indicator is derived by the individual assessment of the alternative employment opportunities in case of lay-off, namely:
If you were to be laid-off, how would you rate on a scale of 1 to 10, the likelihood of you finding a job in the next six months? '1' means that it "would be not at all likely" and '10' means that it "would be very likely".

In addition, a number of individual characteristics such as age, gender, the need for investment in human capital, occupational status and the ability to afford economic obligations are also controlled for in the analysis. At the macroeconomic level, the environmental performance indicator, calculated by the University of Yale, is controlled for. This index incorporates a large number of environmental indicators covering two main aspects, namely environmental public health and ecosystem vitality and greater values indicate better environmental performance of the country. In addition, the Gini income inequality and the labour market protection expenditures are also included in the analysis. The definitions of the variables and the descriptive statistics are displayed in Table 1.

Still, since the analysis includes many countries, it is probable that the individual wellbeing is affected by the social, cultural and legislative context of the country to which each individual lives in (Hox, 2010). An ordinary way to combine micro and macro information in a regression model is to control for both types of variables in the same model but this may lead to serious biasness and to problems such as ecological fallacy (De Leeuw and Meijer, 2008). When the dataset is characterised by a hierarchical system, such as in our case, where the individuals are nested within countries, then it is recommended to utilise multilevel regression techniques in order to control for this nested structure of the dataset (De Leeuw and Meijer, 2008). Ballas and Tranmer (2012) also utilised multilevel regression techniques in a study of wellbeing determinants in the UK, in order to add the regional element into the equations of happiness and to account for the fact that the wellbeing of individuals in the same household, region and/or country is not independent between each other. Multilevel models allows us to estimate different intercepts for the different groups and to model appropriately higher level effects in order to avoid endogeneity bias (Rice and Jones, 1997). In this study the two-level regression model (with level one being the individual level and level two the country level characteristics) with random intercept and random slopes is adopted as described in Hox (2010):

$$\left.\begin{aligned} Y_{ij} &= \beta_{0ij} + \beta_{1j} X_{1ij} + \beta_{2j} X_{2ij} + e_{ij} \\ \beta_{0ij} &= \gamma_{00} + \gamma_{01} Z_j + u_{0j} \\ \beta_{1ij} &= \gamma_{10} + \gamma_{11} Z_j + u_{1j} \\ \beta_{2ij} &= \gamma_{20} + \gamma_{21} Z_j + u_{2j} \end{aligned}\right\} Y_{ij} = \gamma_{00} + \gamma_{10} X_{1ij} + \gamma_{20} X_{1ij} + \gamma_{01} Z_j + \gamma_{11} X_{1ij} Z_j + \gamma_{21} X_{2ij} Z_j + u_{1j} X_{1ij} + u_{2j} X_{2ij} + u_{0j} + e_{ij} \tag{1}$$

Where the subscript *i* denotes the individual level and the subscript *j* denotes the higher, country level ($i = 1,...,n_j$ and $j = 1,...,J$). The intercept and the slope coefficients are allowed to vary across countries ($\beta_{0ij}, \beta_{1j}, \beta_{2j}$) are allowed to vary across countries. The X_{nij} variables are the explanatory variables at the individual level (such as age, job security and the like) whereas the Z_{pj} are the explanatory variables at the country level (such as the environmental protection index) known also as contextual variables. The e_{ij} is the residual term at the individual level with zero mean and a variance that is estimated by the models (Hox, 2010). The u_{0j}, u_{1j}, u_{2j} are random residual errors at the country level with a mean of zero and they are assumed to be independent from the e_{ij} (Hox, 2010). The terms $X_{nij}Z_{pj}$ are the interaction terms and they provide information on the mediating effects of the higher level variables on the observed effect of the individual-level explanatory variables (Hox, 2010).

Due to the complexity of the system of equations estimated, it is less computationally demanding and with easier interpretation of the findings to implement multilevel analysis in continuous explanatory variables (Hox, 2010). Therefore, many researchers tend to ignore the ordinal nature of the dependent variables and treat them as continuous (Ballas and Tranmer, 2012; Hox, 2010). Still, in order to conform to the theoretical findings that indicate that quantitative regression techniques are more appropriate when the dependent variable is ordinal, we proceed to a transformation of the ordinal dependent variables into a pseudo-continuous one by assuming that the cut-off points are drawn by the unconditional sample distribution as proposed by Van Praag and Ferrer-i-Carbonell (2008, 2010). The transformed continuous indicator can be now used with OLS estimators (known as Probit OLS, POLS) and they provide trustworthy estimates while they are used extensively in wellbeing research (Origo and Pagani, 2009).

3. Results

Tables 2-5 presents the POLS regression results (with the “pseudo-continuous” dependent variable) and the multilevel models employed, starting from the null model without any explanatory variables and adding separately the individual-level variables, the macroeconomic (contextual) variables and the cross-levels interactions at the final basic specification model. Table 2 presents the results for life satisfaction determinants with the main focus on job security effects. As seen in the Table, the statistical significance of some explanatory factors turns insignificant when multilevel models are employed. Increased job security feelings are associated with higher satisfaction levels. However, the effect of macroeconomic conditions is not significant. Table 3 presents the respective findings when perceived employability is included as a regressor in the models of life satisfaction. Again, perceived employability feelings are found to affect significantly individual life satisfaction and while the macroeconomic factors are not found to be significant, mediating effects are detected. In detail, for individuals that report increased perceived employability opportunities, an increase in the Gini coefficient by one unit is associated with a 0.015 unit increase in life satisfaction, ceteris paribus. Tables 4 and 5 report the respective results for satisfaction with work regression models. Once again, all individual effects behave in the expected way. Approximately 5%-4% of the variance in satisfaction scores can be attributed to country variations, which is quite small. Still of interest is the mediating effect that labour market protection expenditures exerts on the job security-satisfaction with work relationship. In detail, for individuals who feel secure about their job, a one unit increase in the LPM expenses is associated with an increase in satisfaction with work by 0.075 units.

All in all, the study provides evidence of the effect of work related characteristics upon individual wellbeing. In addition, the findings imply that it is important to control for systematic variations at the country level that may affect the microeconomic determinants of wellbeing. The individual assessments regarding the security of the job and the alternative labour market opportunities are strong determinants of individual wellbeing, although evidence of the “relative position” hypothesis are also detected in line with other studies (Bjørnskov et al., 2008).

Table 1: Variables’ Definitions and Descriptive Statistics

Variable	*Definition*	*Mean*	*Std. Dev.*
Dependent Variables			
Life Satisfaction	Satisfaction with life in general, 1: very dissatisfied – 10: very satisfied	7.62	1.79
Work Satisfaction	Satisfaction with work, 1: very dissatisfied – 10: very satisfied	7.72	1.99
Independent Variables			
Individual Level			
Age	Age in years, 18-77 years	41.64	11.42
Married	1: Respondent is (re)married or single with a partner, 0: otherwise	0.72	0.45
Divorced/Widowed	1: Respondent is separated or divorced or widowed, 0: Otherwise	0.10	0.31
Single	1: Respondent is single, 0: Otherwise (omitted from regressions)	0.18	0.38
Males	1: Respondent is male, 0: Respondent is female	0.49	0.50
Managers	1: Respondent is employed as a manager, 0: Otherwise	0.23	0.42
White Collar Workers	1: Respondent is employed in a white-collar position, 0: Otherwise	0.27	0.45
Blue Collar Workers	1: Respondent is employed in a blue-collar position, 0: Otherwise (omitted from regressions)	0.50	0.50
Training Needs	1: Respondent’s training and education are sufficient to keep his job, 0: Otherwise	0.71	0.45
No Difficulty in Paying Bills	1: Respondent almost never or never experienced difficulty in paying bills last year, 0: Respondent experienced difficulties in paying bills last year from time to time or most of the time	0.60	0.49
Job Security	1: Respondent is fairly confident or very confident that he (she) will keep his (her) job in the coming months, 0: Respondent is not very confident or not at all confident that he (she) will keep his (her) job in the coming months	0.83	0.38
Perceived Employability	1: Respondent is rating the likelihood of finding a new job if laid-off in the next six months above sample average, 0: Otherwise	0.53	0.50
Contextual Level			
EPI	Environmental Performance Index (EPI) of 2010	70.44	29.36
LMP	Labour Market Protection Expenditure as % of GDP	1.64	1.06
GINI	Gini coefficient of equivalised disposable income, scale 0-100	29.36	3.58

Table 2: Life Satisfaction and Job Security Models

Independent Variables	*Model 1 (POLS - Robust s.e.)*	*Model 2 (POLS - By country cluster robust s.e.)*	*Model 3 (Multi level – Null model)*	*Model 3 (Multi level – Random Intercept)*	*Model 4 (Multi level – Random Intercept, Random Coeff.)*	*Model 5 (Multi level – Random Intercept, Random Coeff. with mediating effects)*
Constant	-0.478 ***	-0.478 ***	0.003	0.013	0.023	0.023
Individual Level						
Age	-0.008 ***	-0.008 ***		-0.008 ***	-0.008 ***	-0.008 ***
Married	0.140 ***	0.140 ***		0.170 ***	0.170 ***	0.170 ***
Divorced/Widowed	-0.172 ***	-0.172 ***		-0.137 ***	-0.137 ***	-0.137 ***
Males	-0.034 *	-0.034 *		-0.037	-0.037	-0.037
Managers	0.206 ***	0.206 ***		0.169 ***	0.169 ***	0.169 ***
White Collar Workers	0.019	0.019		0.040 *	0.040 *	0.040 *
Training Needs	0.087 ***	0.087 ***		0.081 ***	0.081 ***	0.081 ***
No Difficulty in Paying Bills	0.407 ***	0.407 ***		0.375 ***	0.374 ***	0.374 ***
Job Security	0.399 ***	0.399 ***		0.370 ***	0.370 ***	0.370 ***
Contextual Level						
EPI	0.005 ***	0.005			0.004	0.004
LMP	0.080 ***	0.080 *			0.064	0.064
GINI	-0.014 ***	-0.014			-0.019	-0.020
Job Security*GINI						-0.0001
R^2	0.15	0.15				
R^2 at the Individual Level				0.10	0.10	0.10
R^2 at the Country Level				0.34	0.46	0.46
F-test	147.47 ***	107.97 ***				
Wald chi2-test				1028.33 ***	1401.82 ***	1935.74 ***
Variance at Individual Level			0.837 ***	0.752 ***	0.00001	0.752 ***
Variance at Country Level			0.105 ***	0.070 ***	0.057 *	0.057 ***
ICC			0.11	0.09	0.07	0.07
Obs.	9,919					

* statistical significant at 10%, ** statistical significance at 5%, statistical significance at 1%.
All variables in multilevel models are grand-mean centered and heteroskedasticity-robust standard errors are calculated.

Table 3: Life Satisfaction and Perceived Employability Models

Independent Variables	*Model 1 (POLS - Robust s.e.)*	*Model 2 (POLS - By country cluster robust s.e.)*	*Model 3 (Multi level – Null model)*	*Model 3 (Multi level – Random Intercept)*	*Model 4 (Multi level – Random Intercept, Random Coeff.)*	*Model 5 (Multi level – Random Intercept, Random Coeff. with mediating effects)*
Constant	-0.535 ***	-0.535 ***	0.003	0.016	0.023	0.028
Individual Level						
Age	-0.005 ***	-0.005 ***		-0.006 ***	-0.006 ***	-0.006 ***
Married	0.138 ***	0.138 ***		0.168 ***	0.170 ***	0.171 ***
Divorced/Widowed	-0.173 ***	-0.173 ***		-0.139 ***	-0.133 ***	-0.132 ***
Males	-0.045 *	-0.045 *		-0.050 **	-0.050 **	-0.051 **
Managers	0.205 ***	0.205 ***		0.163 ***	0.165 ***	0.166 ***
White Collar Workers	0.030	0.030		0.048 *	0.047 *	0.047 *
Training Needs	0.098 ***	0.098 ***		0.092 ***	0.093 ***	0.093 ***
No Difficulty in Paying Bills	0.428 ***	0.428 ***		0.392 ***	0.388 ***	0.388 ***
Perceived Employability	0.276 ***	0.276 ***		0.270 ***	0.262 ***	0.261 ***
Contextual Level						
EPI	0.004 ***	0.004			0.003	0.003
LMP	0.087 ***	0.087 *			0.036	0.038
GINI	-0.010 ***	-0.010			-0.005	-0.019
Perceived Employability*GINI						0.015 **
R^2	0.14	0.14				
R^2 at the Individual Level				0.10	0.10	0.10
R^2 at the Country Level				0.30	0.37	0.40
F-test	140.83 ***	107.43 ***				
Wald chi2-test				883.77 ***	1309.92 ***	1400.73 ***
Variance at Individual Level			0.837 ***	0.753 ***	0.751 ***	0.751 ***
Variance at Country Level			0.105 ***	0.074 ***	0.066 ****	0.063 ***
ICC			0.11	0.09	0.07	0.07
Obs.	9,919					

* statistical significant at 10%, ** statistical significance at 5%, statistical significance at 1%.
All variables in multilevel models are grand-mean centered and heteroskedasticity-robust standard errors are calculated.

Table 4: Satisfaction with Work and Job Security Models

Independent Variables	*Model 1 (POLS - Robust s.e.)*	*Model 2 (POLS - By country cluster robust s.e.)*	*Model 3 (Multi level – Null model)*	*Model 3 (Multi level – Random Intercept)*	*Model 4 (Multi level – Random Intercept, Random Coeff.)*	*Model 5 (Multi level – Random Intercept, Random Coeff. with mediating*
Constant	-0.714 ***	-0.714	0.003	0.012	0.006	0.007
Individual Level						
Age	-0.001	-0.001		-0.002	-0.002	-0.002
Married	0.024	0.024		0.033	0.032	0.031
Divorced/Widowed	-0.048	-0.048		-0.043	-0.043	-0.043
Males	-0.019	-0.019		-0.019	-0.018	-0.018
Managers	0.210 ***	0.210 ***		0.187 ***	0.188 ***	0.188 ***
White Collar Workers	0.003	0.003		0.028	0.030	0.030
Training Needs	0.70 ***	0.70 **		0.071 ***	0.070 ***	0.070 ***
No Difficulty in Paying Bills	0.288 ***	0.288 ***		0.283 ***	0.282 ***	0.283 ***
Job Security	0.517 ***	0.517 ***		0.517 ***	0.542 ***	0.542 ***
Contextual Level						
EPI	-0.001	-0.001			-0.001	-0.001
LMP	0.020 **	0.020			0.007	0.013
GINI	0.002	0.002			0.001	0.002
Job Security*LMP						0.075 ***
R^2	0.09	0.09				
R^2 at the Individual Level				0.08	0.08	0.08
R^2 at the Country Level				0.30	0.32	0.32
F-test	83.22 ***	39.34 ***				
Wald chi2-test				714.46 ***	922.91 ***	1010.38 ***
Variance at Individual Level			0.893 ***	0.822 ***	0.820 ***	0.820 ***
Variance at Country Level			0.051 ***	0.040 ***	0.035	0.035 ***
ICC			0.05	0.04	0.04	0.04
Obs.	9,919					

* statistical significant at 10%, ** statistical significance at 5%, statistical significance at 1%.
All variables in multilevel models are grand-mean centered and heteroskedasticity-robust standard errors are calculated.

Table 5: Satisfaction with Work and Perceived Employability Models

Independent Variables	*Model 1 (POLS - Robust s.e.)*	*Model 2 (POLS - By country cluster robust s.e.)*	*Model 3 (Multi level – Null model)*	*Model 3 (Multi level – Random Intercept)*	*Model 4 (Multi level – Random Intercept, Random Coeff.)*	*Model 5 (Multi level – Random Intercept, Random Coeff. with mediating effects)*
Constant	-0.714 ***	-0.714 ***	0.003	0.015	0.016	0.016
Individual Level						
Age	0.001	0.001		0.001	0.001	0.001
Married	0.026	0.026		0.035	0.036	0.037
Divorced/Widowed	-0.046	-0.046		-0.043	-0.041	-0.040
Males	-0.030	-0.030		-0.031	-0.031 *	-0.032 *
Managers	0.217 ***	0.217 ***		0.191 ***	0.191 ***	0.190 ***
White Collar Workers	0.017	0.017		0.041	0.042 **	0.041 **
Training Needs	0.088 ***	0.088 ***		0.091 ***	0.092 ***	0.092 ***
No Difficulty in Paying Bills	0.324 ***	0.324 ***		0.317 ***	0.316 ***	0.316 ***
Perceived Employability	0.277 ***	0.277 ***		0.267 ***	0.265 ***	0.264 ***
Contextual Level						
EPI	-0.0001	-0.0003			-0.001	-0.001
LMP	0.029 ***	0.029			0.020	0.019
GINI	0.006 ***	0.006			0.002	0.002
Perceived Employability*LMP						-0.031
R^2	0.07	0.07				
R^2 at the Individual Level				0.06	0.06	0.06
R^2 at the Country Level				0.24	0.24	0.24
F-test	66.59 ***	22.86 ***				
Wald chi2-test				361.34 ***	539.86 ***	533.57 ***
Variance at Individual Level			0.893 ***	0.839 ***	0.838 ***	0.838 ***
Variance at Country Level			0.051 ***	0.039 ***	0.039 ***	0.038 ***
ICC			0.05	0.04	0.04	0.04
Obs.	9,919					

* statistical significant at 10%, ** statistical significance at 5%, statistical significance at 1%.
All variables in multilevel models are grand-mean centered and heteroskedasticity-robust standard errors are calculated.

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Exploring organizational accountability in relation to climate change: Where do Greek corporations stand?

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Abstract
An increasing number of large corporations around the world engage in accounting for and reporting on their plans and measures towards climate change, as part of their environmental responsibility agenda. Using a disclosure index, this study investigates the status of the disclosure practices of the top 100 companies operating in Greece with respect to the pivotal issue of climate change. Determinants which drive Greek companies to publicly disclose such information are examined while overlapping perspectives for the Greek case are outlined. The analysis suggests that only a small group of leading Greek companies appears to endorse a climate change discourse as an instrument of empowering stakeholders' decision-making. Most other corporations still tend to disregard disclosure practices of their actions towards this global issue.

Keywords: Climate change, corporate disclosure, regression analysis, corporate social responsibility, content analysis, Greece.

1. Introduction

Climate change poses potentially unprecedented threats to modern societies and reflects a much-debated issue as it is strongly interlinked with current lifestyles and development policies. While scientific assessments suggest that the overall impact from climate change is most likely unpredictable, they seem to denote that extreme weather conditions are to be expected among the various geographical regions in the years to come. Moreover, such unpredictability refers to significant changes in the distribution of precipitation, affecting the intensity and frequency of draughts and floods, severe disease and pest outbreaks and well as widespread fires in forested areas.

The need for co-ordinated action to mitigate climate change impacts is an essentially complex public policy problem of modern times; a problem where meaningful actions from the business community should represent a key component in shaping effective policy responses and appropriate mitigation measures. Given the difficulties of the global community in defining concrete ways to confront climate change, the exploration of the discretionary disclosure of organizational responses to climate change makes a useful endeavour. Moreover, under the critical circumstances climate change posits, companies need to maintain the support and approval of their stakeholders by introducing or refining practices that will counteract possible legitimacy threats or risks related to climate change.

2. Background – Conceptual underpinnings

Discretionary corporate climate change disclosure (CCD) has been identified as a valuable legitimation instrument which can mitigate conflicts with stakeholders and a practice with a mediating effect in convincing societal members that the organization is fulfilling their expectations (Dowling and Pfeffer, 1975; Lindblom, 1994). The concept of legitimacy according to Dowling and Pfeffer (1975, p.122) is defined as "a condition or status which exists when an entity's value system is congruent with the value system of the larger social system of which the entity is a part' and add that 'when a disparity, actual or potential, exists between the two value systems, there is a threat to the entity's legitimacy". Legitimacy theory posits a systems-oriented perspective to the business-and-society relationship, where the firm influences and is influenced by the social context within it operates. It sets forth a form of a 'social contract' where society provides the company with a range of resources to conduct its activities along with an overarching 'licence to operate', in return for the provision of socially acceptable (i.e. legitimate) business conduct (Mathews, 1993; Deegan, 2002). Whenever the organization's operation is not meeting the society's set of norms and values then the latter can revoke its 'licence' and for the firm to retain its legitimacy practical demonstrations of adherence to such expectations are essential.

According to Gray et al. (1987), such disclosure practice refers to "the process of communicating the social and environmental effects of organizations (particularly companies) beyond the traditional role of providing a financial account to the owners of capital, in particular shareholders. Such an extension builds upon the assumption that companies do have wider responsibilities than simply to make money for their shareholders" (Gray et al., 1987, p. 9). In line with the multidimensionality of the corporate social responsibility (CSR) construct, CCD encompasses a diverse range of information, including vision and strategic posture to address climate change, risks and opportunities arising from climate change, investment plans to mitigate operational impact and control emissions, quantitative information of greenhouse gas emissions, voluntary initiatives to reduce emitted greenhouse gases, etc.

A considerable number of the largest corporations around the world adds emphasis and allocates resources towards climate change mitigation plans and measures (Carbon Disclosure Project, 2013). In this respect, corporations are called upon to shape voluntary disclosure practices for such courses of action in order to address potential legitimacy deficits (Kolk, 2008). Indeed, the overlapping and multifaceted impacts of climate change are acknowledged as significant and far-reaching for business (Business Roundtable, 2007). Still, relevant corporate communication channels which incorporate such considerations leave much to be desired with Doran et al. (2009) to indicate that a mere 24% of the Standard and Poor's (S&P) 500 companies referred to climate change in their SEC filings.

CCD has received increased attention in the academic literature with a growing number of empirical studies to explore this aspect of corporate accountability. In this regard, two dominating groups of research streams are identified. A considerable number of scholars focus on trends and patterns of CCD in specific national-regional and/or industries while another group of studies attempts to shed light on determinants and predictors of CCD (e.g. Stanny and Ely, 2008; Freedman and Jaggi, 2009).

With this in mind, this study aims to make empirical contributions to the prior literature by shedding light on the comprehensiveness of CCD by large firms in Greece and investigate a number of determinants for such disclosures. Next, the hypotheses of the study are described along with the methods employed and the sample identification. The following section presents the analysis of data and relevant findings. In the final section, implications are discussed and remarks regarding the Greek case are drawn.

3. Hypotheses development

Prior research suggests a positive relationship between corporate size and the extent to which corporations disclose information (Ahmad et al., 2003; Freedman and Jaggi, 2009; da Silva Monteiro and Aibar-Guzmán, 2009; Stanny and Ely, 2008). Larger organizations encapsulate high public visibility and significant social and environmental impacts (Watts and Zimmerman, 1986). They also have more resources to invest in CCD (Belal, 2001) and aim to present a positive image towards their stakeholders. Therefore, we hypothesize that:

H1: CCD of Greek firms is dependent on organizational size.

Literature also suggests a strong industry effect on environmental and social disclosure. In particular, companies in the mining, oil and chemical sectors seem to disclose more information regarding environmental management and employees' health and safety measures (Line et al., 2002), while the financial sector, and the tertiary-service sectors in general, seem to give more emphasis to labour practices, product responsibility and broader social issues (Line et al., 2002). In addition, corporations in sectors with high environmental sensitivity tend to disclose more information regarding their environmental performance than others (Hackston and Milne, 1996; Patten, 1991; Roberts, 1992; Ahmad et al., 2003; da Silva Monteiro and Aibar-Guzmán, 2009). Finally, business organizations with high proximity to the final consumer (i.e. companies of the banking, retailing, utilities or food and beverages sector) are expected to provide more non-financial information in general (Arulampalam and Stoneman, 1995), since promoting a positive corporate image that assures responsible conduct, increases brand loyalty and motivates consumers to buy products of the specific brand (Meijer and Schuyt, 2005). Thus, we postulate the following hypotheses:

H2: CCD of Greek firms varies by business sector.

H2a: Greek companies pertaining to environmentally sensitive sectors will provide more CCDs.

H2b: Greek companies with high proximity to the final consumer will provide more CCDs.

Prior findings on the relationship between business profitability and non-financial disclosure are ambiguous (e.g. Belkaoui and Karpik, 1989; Patten, 1991; Roberts, 1992). Nevertheless, increased profitability can have a direct effect on the extent of environmental and social disclosure (Bo, 2009). Supporting arguments for this claim point out that a profitable organization is more exposed to social scrutiny (Ng and Koh, 1994), and is most likely managed by skilled and insightful executives who can potentially foresee the benefits of social responsiveness (Belkaoui and Karpik, 1989), but mostly that it has the available economic resources to engage in voluntary disclosure (Hackston and Milne, 1996; Roberts, 1992). Thus, the following hypothesis is postulated:

H3: CCD of Greek firms is dependent on profitability.

Chapple and Moon (2005) argue that the level of internationalization of a firm can lead to increased CSR and, in our case, to increased CCD efforts. They denote that "...as businesses trade in foreign countries, they see the need to establish their reputations as good citizens in the eyes of new host populations and consequently will engage in CSR as part of this process" as well as that "...the emerging systems of world economic governance create incentives for greater CSR" (p. 419). In a similar vein, Cooke (1989) and Tang and Li (2009) stress that a firm's presence in foreign markets postulates that it is bound to disclose more comprehensive information in line with the reporting rules of the foreign business system. In addition, Robb et al. (2001) offer empirical support that international presence can be a strong determinant for non-financial disclosure. In line with these arguments, we formulate the following hypothesis:

H4: CCD of Greek firms depends on their level of internationalization.

Isomorphic patterns and mimetic processes as reflected in the subscription to business coalitions and self-regulatory initiatives for promoting CSR (DiMaggio and Powell, 1983; Matten and Moon, 2008) have a mediating role in the non-financial disclosure practices of firms. In this context, the growing number of stand-alone CSR reports in Europe (KPMG, 2013) has been identified as a marking example of such processes in the homogenization of institutional environments across national boundaries (Matten and Moon, 2008: p. 412). In view of the above, we hypothesize that:

H5: Members of the Hellenic CSR Network and the Greek Business Council for Sustainable Development provide more CCDs.

Secchi's (2006) evidence from Italy reveals that there is heterogeneity in the non-financial reporting practices of government-owned and privately-owned firms. In this respect, the size of the (notably larger) strongly bureaucratic, centralized public sector in Greece has aggravated calls for new public management techniques (Phillipidou et al., 2004). Yet, efforts towards the modernization of the state are admittedly slow and previous transformational processes have proved unsuccessful (Kufidou et al., 1997; Philippidou et al., 2004). Key factors for such failure include Greek state organizations' resistance to change, the myopic focus on regulations, the absence of robust strategic planning, the lack of employee motivation and stimuli to undertake initiatives in order to offer and apply new thinking in the organization (Ministry of Internal Affairs, 2000 in Phillipidou et al., 2004: p. 324).

Moreover, according to preliminary arguments and tentative findings (Tsakarestou, 2004; Hackston and Milne, 1996; Tang and Li, 2009), it is reasonable to hypothesize that subsidiaries of foreign multinationals (MNCs), which have adopted a robust CSR agenda, can act as moral agents in the country and will be more active in non-financial disclosure than those companies headquartered within the country.

Finally, companies listed on the Athens Stock Exchange (ASE) constitute 'the 'core' of the country's corporate sector, represent major sectors of economic activity and form an essential driving force of the domestic economy via their linkages with other, non-listed, enterprises. These firms are not only well-known to the financial and business analysts' community, but they tend to draw more public attention and receive more extensive media coverage than unlisted firms (Branco and Rodrigues, 2006). Given these, the following hypotheses are posited:

H6: CCD of Greek firms varies by ownership identity.

H6a. Greek government-owned and government-linked corporations provide less CCDs.

H6b: Subsidiaries of foreign MNCs provide more CCDs.

H6c: Companies listed on the Athens Stock Exchange provide more CCDs.

Finally, prior literature suggests that companies with greater exposure to social scrutiny have a strong incentive to employ disclosure in an attempt to address the negative effects of such exposure on organizational image and reputation (Hughes et al., 2001; Patten, 2002; Cho and Patten, 2007, Cho et al. 2012). In Greece such firms are those located in the environmentally degraded area of Asopos area which has been on the headlines for over a decade for incidents of heavy pollution of the underground water reserves due to high concentration of hexavalent chromium residues and an associated high cancer rate of the local population. Over the years, calls for increased environmental and social responsibility have been expressed by governmental bodies and inspector agencies as well as local communities and NGOs regarding their operation. With this in mind, and taking into account the conceptual underpinnings of legitimacy theory we hypothesize that:

H7: Companies facing intense social scrutiny and pressure will provide more CCDs.

4. Material and methods

The sample used in this study consists of the 100 largest companies operating in Greece (based on annual revenues) according to the ICAP's annual "Greece in Figures" report. Out of the companies in question, 32% belong to the manufacturing sector, followed by firms engaged in trade/retail activities (31%), the banking-insurance sector (12%) and the utilities sector (11%). No other business sector yielded more than 10% of the sample (construction and building materials firms represent 6% while firms pertaining to other tertiary/service sectors represent 9% of the sample). Moreover, 36% of the firms are listed in the ASE, 7% are government-owned, and 29% are privately-owned while 28% are subsidiaries of foreign multinationals.

In order to explore the publicly available CCDs, a web-based search was performed during the first quarter of 2011, locating the official websites of the sample companies and all the related information (annual reports, environmental statements, press releases, webpages, etc.) was identified. In cases of annual, stand-alone, non-financial reports (environmental, health and safety, CSR and/or sustainability), the most recent one was included in the analysis. Among the 100 corporate websites, one was under construction while three foreign subsidiaries redirected interested parties to the global website of the parent company.

CCD is assessed according to a numerical grading scheme where zero for equals to non-disclosure, 1 if the organization discloses brief and/or insufficient information and 2 if it provides extensive coverage and/or comprehensive material on the specific topic.

Independent variables

Company size is measured by the number of employees and turnover (% of variance explained = 76.5%).

Business sector is measured by a six-scale dummy variable pertaining to the segmentation of the top Greek firms presented in the sample's description.

Profitability is measured using return on equity (ROE) and return on assets (ROA) (% of variance explained = 84.6%).

Internationalization is operationalized by the percentage of sales exported to other countries as well as by the number of countries, besides Greece, where the organization operates (% of variance explained = 67.1%).

Environmental sensitivity, consumer proximity and subscription to CSR initiatives are also expressed by a binary zero/one dummy variable, where one designates a company falling in these categories and zero if it is does not.

Ownership identity is measured by a four-scale dummy variable pertaining to the segmentation of the top Greek firms presented in the sample's description.
Social pressure is measured by a binary zero/one dummy variable to distinguish between the companies operating in the greater Asopos area and the rest of the companies.

Ordinal Logistic regression analysis

To identify those factors which (statistically) significantly influence CCD of Greek companies and for the construction of a statistical model we have opted for fitting a logistic regression model to the data collected. This has important ramifications for the guiding hypotheses we have formulated. In such a model the outcome variable is predicted from a combination of most important prior/predictor variables employed in the model. A set of independent variables both categorical and continuous quantitative can be employed, investigating the possibility of an event to occur which is represented by a categorical dependent variable. With ordinal logistic regression, the categorical regression quantifies categorical data variables to yield numerical values to the categories, aiming at the optimal linear regression of transformed variables (Agresti, 2012). The ordinal logistic regression model is a modified model of binary logistic regression, incorporating the categorical nature of the dependent variable defining the different categories. If the categories of the dependent variable is j then the odds ratio for each category is:

$$\theta_j = prob(category \leq j) / prob(category > j) \text{, or}$$
$$\theta_j = prob(category \leq j) / 1 - prob(category \leq j) \qquad (1)$$

The ordinal logistic regression model for each dependent category is then:

$$\ln(\theta j) = \alpha\, j - (\beta 1X1 + \beta 2X2 + \ldots\ldots\ldots\ldots + \beta nXn) \qquad (2)$$

where j takes values from 1 up to the number of classes -1 and n is the number of independent variables. The negative sign of the coefficients indicates that the major factors associated with larger categories. When we have a positive coefficient in a category of an ordinal logistic regression categorical predictor we have indications that belonging to this category increases the odds of being in a higher level of the dependent. Likewise, negative coefficients indicate that a decrease in odds is more likely. For a continuous variable, the positive coefficient indicates that with increasing the value of this variable then the probability for the higher categories is increased. This means less cumulative probability for the lower categories as they are less likely to occur.

In this study, the logistic regression analysis is performed in order to examine which of the research variables have the greatest power in predicting the ordinal variable of CCD.The econometric analysis was performed using the statistical package SPSS 19.0 (SPSS, 1999) including the descriptive analysis of individual variables from the questionnaire, and the analysis of qualitative variables using ordinal logistic regression, attempting to identify potential characteristics which affect the views of business organizations on issues such as climate change.

A stepwise selection procedure (backwards elimination) was utilized for obtaining the most significant predictor estimates in model fitting, avoiding in this way overfitting. Also, goodness-of-fit measures are reported for assessing the adequacy of model fit.

5. Results

5.1 Descriptive results

As concerns the CCD behavior on behalf of the companies operating in Greece, the descriptive analysis of our sample shows that the sizable majority of the companies (74%) take no measures at all for disclosure, with only a 12% and a 14% of the organizations disclosing brief/insufficient information and providing extensive coverage, respectively. It is obvious from the above that the dialogue potential CCD encapsulates is not utilised effectively to enable and stimulate a fruitful accountability parameter. Quantitative information is very little, mostly located in CSR reports and absent from annual reports and investor relations statements.

The following table (Table 1) presents spearman's correlation coefficients (ρ) between the various categorical items utilized in the subsequent statistical analysis. Most significant correlations exist between sector and type of activity ($\rho = 0.807$, p-value<0.001), consumer proximity and environmental sensitivity ($\rho = -0.554$, p-value<0.001) and CCD and CSR initiatives ($\rho = 0.532$, p-value<0.001).

Table 1: Spearman's correlations for the ordinal variables

	CCD	Social Pressure	Sector	Ownership identity	Environmental sensitivity	Consumer proximity	CSR initiatives
CCD	1						
Social Pressure	0,146	1					
Sector	0,025	-,367(**)	1				
Ownership identity	-,258(**)	-0,186	-0,189	1			
Environmental sensitivity	,212(*)	0,179	-,240(*)	-,223(*)	1		
Consumer proximity	0,066	-0,009	,213(*)	0,031	-,554(**)	1	
CSR initiatives	,532(**)	0,071	0,044	-0,142	0,174	-0,058	1

**Correlation significant at the 0.01 level (2-tailed). *Correlation significant at the 0.05 level (2-tailed).

5.2 Results of statistical analysis

The results of adapting appropriate ordinal logistic regression model are included in the following table, where CCD is employed as the dependent variable. Specifically, Table 2 shows results (estimates regression coefficients, corresponding 95% confidence limits and the statistical significance) of the ordinal logistic regression model where we assess the effects of the various companies' characteristics on CCD. Table 2 refers only to the significant predictors of the ordinal logistic regression analysis. As one observes, most important predictors of CCD are the company size, ownership identity and subscription to CSR initiatives. The rest of the initially hypothesized predictors were not deemed significant from the results of the analysis.

Most of the predictors are only marginally important with only company size to appear as having a substantial effect on CCD (beta = 3.348, p-value<0.001). Thus, for company size, we would say that for a 1 unit increase in company size we would expect a 3.348 increase in the ordered log odds of being in a higher level of CCD (i.e. comprehensive climate change information). On the contrary, companies that are not subscribed to domestic CSR initiatives are decreasing the log odds of being in a higher level of climate change policy.

The same holds for those companies that are listed in ASE, when compared with all other company categories (i.e. companies that are subsidiaries of foreign company, Privately/Government-owned companies). Those listed in ASE have a reduced probability on presenting detailed information with relation to climate change.

Table 2: Parameter estimates and corresponding significance for the ordinal logistic regression model

Dependent variable: Climate Change Disclosure (reference category: Comprehensive information)			
Parameter	estimate	95% C.I.	p-value
Non disclosure	-7.478	(-426, 411)	0.972 (n.s.)
Brief information	-5.281	(-423, 413)	0.980 (n.s.)
Company size	3.348	(1.139, 5.557)	0.003***
Ownership Identity (reference category: Subsidiary of foreign company)			
Listed in ASE	-2.064	(-4.274, 0.146)	0,067*
Privately-owned	-1.425	(-3.51, 0.659)	0,180 (n.s.)
Government-owned	-24.344	(267.1, 218.45)	0,844 (n.s.)
Subscription to CSR initiatives (reference category: YES)			
No	-1.56	(-3.155, -0.036)	0.055*
Pseudo R Square			
Cox & Snell R Square	0.778		
Nagelkerke R Square	0.99		
McFadden	0,99		

(*) coefficient is significant at a 10% level of significance
(**) coefficient is significant at a 5% level of significance
(***) coefficient is significant at a 1% level of significance
n.s.: non-significant

As concerns the model's adequacy, the Nagelkerke's pseudo-R was 0.99, and Cox and Snell R-square 0.778, indicating a good fit. In overall, the corresponding final estimated regression equation for the dependent category of comprehensive information for the CCD is given by:

$$\ln\left(\Pr\left(\frac{non\quad comprehensive\quad \inf ormation}{comprehensive\quad \inf ormation}\right)\right) = -5.281 - (3.348 * XSIZE - 2.0 * XLISTED\ INASE - 1.56 * XNO\ CSR\ INITIATIVES) \quad (3)$$

As a consequence of the latter analyses, we may state that our hypotheses postulations are only partly verified, by only accepting hypotheses H1, H5 and H6[72], rejecting all of the rest.

[72] Note that although we have found evidence that CCD of Greek firms varies by ownership identity (H6), sub-hypotheses H6a, H6c were not verified, with only subsidiaries of foreign MNCs been found to provide more CCDs as hypothesized (H6b).

6. Concluding remarks

Deegan et al. (2002) assert that "where there is limited concern, there will be limited disclosures" (p.335). In this respect, our findings suggest that Greek companies are most likely overlooking or disregarding CCD. Apart from a very small sub-group of Greek firms actively engaged in the endorsement of CCD practices, most other assessed corporations tend to treat such accountability perspectives superficially and in a 'window-dressing' manner, offering primarily self-laudatory information. Given that gathering and sharing climate change information can be conceived as a reflection of a firm's related performance as well as a useful 'proxy' to assess it (Snider et al., 2003), most assessed firms appear to undertake inadequate actions towards the identification of their exposure to climate change risks and implicit opportunities.

Such information deficit fails to inform stakeholders' decision-making and adds very little to environmental policy and planning. Yet, domestic market forces (suppliers, customers, investors, creditors, etc.) and bottom-up pressures (from civil society actors and the wider public) in challenging the environmental accountability of business have so far been weak and sporadic in Greece. Awareness, interest and knowledge in environmental management are low (Kassolis, 2007) while 'domestic mobilization' (Börzel, 2003) has generally been slack. Stakeholders' demands and expectations have so far proved to be moderate in stimulating the Greek business community towards consistent environmental reporting and meaningful environmental management.

Future research should investigate CCD in other national contexts using more detailed content analysis approaches. Moreover, longitudinal analysis of CCD could contribute in examining whether and how the recent economic downturn affected the climate change discourse of corporations. Finally, action research and qualitative evidence could shed light on where climate change stands among the various corporate reporting aspects and, ultimately, provide additional insights into factors that determine accountability responses towards this global concern.

Acknowledgements
This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: THALES - Investing in knowledge society through the European Social Fund.

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The Sustainable (Eco) Innovation Output in the OECD Area: a Patent Analysis

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Abstract
This paper studies and measures the output of sustainable innovation in the OECD area. Results are based on patent records and their use as indicators of innovation output. Results show that sustainable innovation accounts for 6.97%, with the fields 'general environmental management' and 'emissions abatement and fuel efficiency in transportation' being the most important. The former is further related to technologies of 'air and water pollution abatement and management', 'waste management' and 'material recycling'. The latter is further related to technologies of 'propulsion' and 'fuel efficiency- improving vehicle design'. Results also show that the best sustainable innovators Slovak Republic, Luxembourg, Greece, Denmark and Japan. Thus, the comparative high or low national innovation output in sustainable (eco) fields doesn't seem to depend on the national economic and/or technological level, but perhaps on the national technological choices and needs. On the contrary, USA which is the larger patent holder is classified relatively low in the sustainable (eco) ranking, characterized by an advantage in only one field, namely that of 'technologies specific to climate change mitigation'.

Key Words: Eco- innovation; output, measurement; patents; sustainable innovation.
JEL Codes: O31; O34; O57; Q59.

1. Introduction

The concept of innovation is more or less widely known. Innovation has become a very important factor to corporate success, technological leadership and economic development, both at regional and national level (Buswell, 1987; Malecki, 1991). Schumpeter (1943), with his "gales of creative destruction", gave a vivid description of the effects of the introduction and diffusion of major technological discoveries and inventions in industry and the world economy and Romer (1994) emphasized the role of innovation. As a production factor innovation affects growth and contributes to the development of nations. According to Porter (1991), innovation, whether it relates to processes, products or organizations, determines the competitiveness of a nation, which depends ultimately on the companies' ability to innovate and improve. Innovation is the output of the innovation process, which is considered to be a highly systemic and complex process, which varies across industry, technology and firm size. Particularly for firms, firms develop innovations responding to their particular markets needs and technological challenges.

The term sustainable is fairly recent. It has been related to the target of development, introducing the concept of sustainable development. Sustainable development is the development that satisfies the needs of today without risking the capacity of the future generations to satisfy their own needs (OECD, 2006). Innovation is central to sustainable development and, in this context; sustainable innovation is the development of products and processes that contribute to sustainable development, applying the commercial application of knowledge to elicit direct or indirect ecological improvements. This includes a range of related ideas, from environmentally friendly technological advances to socially acceptable innovative paths towards sustainability. In this context, the concept of sustainable (eco) innovation has been created and introduced to describe the development that satisfies the needs of today without risking the capacity of the future generations to satisfy their own needs. Thus, the parameters of environment and ecology are central or even predominant in sustainable innovation, to such as extent that sustainable innovation could be defined as eco or environmental- innovation, which is the innovation that faces the problems of both climate change and environment (e.g. optimize the use and exploitation of natural resources, save energy, promote the ecological building, contribute to sustainable agriculture, etc.).

The paper is structured as follows: Section one is the introductory part of the paper, where the theoretical and empirical framework of innovation in relation to competitiveness, development and growth is discussed. Section two describes how the sustainable (eco) innovation can be measured and provides arguments for and against the use of patent data for the measurement of sustainable (eco) innovation output, ending up to the conclusion that patents may be considered and accepted to be good and reliable indicators of innovation output. Section three describes the data that has been used and the methodology that has been followed for this study. Section four describes the research results. Section five presents the main conclusions of the paper, synthesizing and further discussing the results. To the best of the knowledge the paper is original in the sense that there is no record of research and study having studied the above issue and provided a comparative analysis of the production of sustainable (eco) innovation output in the OECD area based on patent data at country level.

2. Theoretical and empirical evidence

The production of innovation plays a very important role in economic development, of which the issue of sustainability is very important. Sustainability in development or alternatively sustainable development relies on the production of eco-innovation, namely innovation that optimizes the use of natural resources, save energy, promote the ecological building, contribute to sustainable agriculture, etc.

Since the pioneering study on the nature of innovation in the 1970s, (Gibbons & Johnston, 1974; Freeman, 1974), many works have been presented regarding innovation analysis. Innovation is the output of innovation process. Innovation process is considered to be a highly systemic and complex process, which varies across industry, technology and firm size. Particularly for firms, firms develop innovations responding to their particular markets and technological challenges. All these factors make innovation difficult to be measured in complete and standardized ways. However, given the importance of innovation for national and firm wealth and welfare, the issue of measurement has become even more demanding. Nowadays, the literature on measurement of innovation is abundant, every day being improved and increased, and focused on measuring innovation at both firm, sector, regional and national level, as well as in combination to other economic and managerial parameters. The main methodological conclusion derived from the study of literature is that innovation can be measured only through its products and only indirectly, with the contribution of relative indicators. One very important category of such indicators is patent indicators.

A patent is an invention only if the innovation that this invention 'hides' is novel, involves a non-obvious inventive step, and could be commercially viable (Dernis and Kahn, 2004). Among the advantages of using patent data at the study of technological innovation are first their easy accessibility, high reliability and precise definition (Ernst, 2001). Second patent data are accurately recorded and easily elaborated, while they can be used to examine and study different levels and kinds of analysis (Griliches, 1990). Third, patent data are rather 'objective' indicators, as patent documents are examined and eventually granted by a single national patent office. Finally, in comparison with or in contrast to other sources, patents are often the only timely measure of rapid technological change, particularly in the context of global competition. However, as every tool of analysis, patent data exhibit also limitations. First, every patent office treats patents equally, while they are not and nor do all patents exert the same economic impact and the same technological and economic value (Wang , 2007; Lee, 2009). Second the propensity to patent differs across countries, sectors and firms and this difference overestimates or underestimates the results in terms of performance (Makinen, 2007). Meanwhile this difference is due in part to the level of protection afforded by the patent, but also to the possibility of protecting monopoly rights by other means depending upon market conditions. Third, there are differences in patent regimes across countries and this means that it is difficult to be certain that one is comparing 'like with like'. For instance, some countries would require multiple patents for the same innovation which could be covered by a single patent in other countries.

The great majority of studies and reports aiming at the study of sustainable (eco) innovation has used as a main method of analysis patents or alternately survey analysis. For example, Lanjouw and Mody (1996) counted the number of patents in nine environmental fields (including alternative energy) and studied the issue of diffusion of environmental technologies based on international patent data are used to track patterns of diffusion. Popp also used patent citations to study environmental innovation, while later on he studied the pollution control technologies. Oltra and St Jean (2009) studied the level of eco-innovation activities, the directions of research in certain environmental fields and their historical evolution, a parameter which was also studied by Frenken (2004). These researchers also dealt with the competencies of organizations in environmental technologies focusing on the field of low emission vehicles (LEVs). On the other hand the study of Nameroff (2004) and his colleagues focused on green chemistry patents based on US patent data. Their research ended up with the identification of 3235 green chemistry US patents. Johnstone et al. focused on renewable energy patents.

Finally, Marinova and McAleer (2003) studied the environmental technology strength of nations with the use of patent data, finding that Germany is the best performing country in a group of 12 countries, and Canada and Japan ranked equal second. In an attempt to group the above studies and reports based on their main purpose of analysis, three kinds of research purposes could be identified: First, studies and reports aiming at measuring the rate and direction of invention, which can be mapped and can be related to possible determinants. Second, studies and reports aiming at determining spillover effects, monitoring diffusion and determining relative specialization/ strength of nations in certain technology areas. Third, studies and reports allowing for comparative analysis across nations for technologies. The limitations of the above analysis, which are related to the general limitations of using patents in measuring innovation, are recorded in the majority of the above studies and reports. For example and focusing on the sustainable (eco) parameter, it has been argued that the identification of eco-patents depends critically on search terms and that patent analysis only suited for technological innovations (primarily end-of-pipe technologies and alternative energy technologies).

3. Methodology: Collection of data and elaboration

The data for this study is based on the OECD patent database (OECD, 2012). The main issue with this kind of data and in relation to the research aim of the paper is the method in use for the identification of sustainable (eco) patents. Two methods have been used so far. The first method is based on the examination of all codes classified to each patent according to the international technology classification (IPC) and in relation to sustainable (eco) matters. Thus, the first method focuses on the technological content of each patent as derived from its assignment to one or more patent codes and its interpretation. The second method relies on the 'creation' of keywords which should be also closely related to sustainable (eco) matters. Thus, the second method scans every patent in a dual way, both its short description and the interpretation of the technological content of each patent searching for these keywords. Therefore, it could be argued that results depend on what and how the term sustainable (eco) is defined. Obviously, the use of patents documents to measure sustainable (eco) innovation could raise strong methodological issues. Their identification implies time and data consuming methodologies based on IPC classifications and on relevant keywords.

Based on the OECD methodology, the OECD patent database classifies sustainable (eco) patents in the following fields: a) renewable-alternative energy and resources (solar, hydro, wind, geothermic), b) technologies related to vehicles (e.g.. electrical and hybrid vehicles), c) energy technologies related to house-domestic, commercial and industrial sectors (e.g. insulation, heating, lighting, cement industry), d) recycling (e.g. reusing waste), e) elaboration of waste and their disposal (e.g. radioactive, solid, waste water, waste' incineration), f) technologies related to pollution (e.g. air, industrial, vehicle, water cleaning technologies), g) technologies that protect from the noise, h) cultivations and activities of the agricultural sector, j) rest technologies in relation to monitoring equipment and other applications.

As already mentioned, the analysis is based on patent data. In fact, data has been extracted from the OECD patent database. More specific, a database has been constructed, which contains all patents granted by the European Patent Office (EPO) for the total of OECD countries (34 countries) and for a period of 13 years (1999-2011). In addition, the period of analysis has been divided into two sub-periods: Period 1 (1999-2005) and Period 2 (2006-2011). Results are based on the construction of indicators of overall national and sectoral performance, growth rates for the whole period of analysis and the two sub-periods and the RSTA (Revealed Sustainable- Technological Advantage) for the whole period of analysis and for the main sustainable (eco) sub-fields. The sectoral Revealed Sustainable- Technological Advantage (RSTA) is based on the previous way of calculation for the 7 main sustainable (eco) fields, namely those of (1) general environmental management, (2) energy generation from renewable and non-fossil sources, (3) combustion technologies with mitigation potential, (4) technologies specific to climate change mitigation, (5) technologies with potential or indirect contribution to emissions, (6) emissions abatement and fuel efficiency in transportation and (7) energy efficiency in buildings and lighting. The methodology centres on defining the sustainable (eco) patent and searching for it, which relies on the creation of keywords and the examination of the relevant patent codes. The calculation of the RSTA (Revealed Sustainable- Technological Advantage) is based on the following type: [Patents in sustainable fields for country 1/ all patents for country 1]/// [Patents in sustainable fields for the total OECD area/ all patents for the OECD area].

4. Results

4.1. Total and sectoral sustainable (eco) trends: Analysis at main and sub- fields level

Table 1 shows that the sustainable (eco) innovation accounts for 6.97% totally, namely for the total of the OECD countries and based on the patents records of the European Patent Office (EPO). The total production of sustainable (eco) innovation grew on 119.30% with a mean annual growth of 4.47% and a concentration index based on the Herfindhal indicator of 0.27 during the period 1999-2011. Dividing between the two time periods under examination (1999-2005 and 2006-2011) the total sustainable (eco) patent share is increased from 6.64% to 7.28%, while the concentration index ranges from 0.27 for the period 2006-2011 and 0.28 for the period 1999-2006.

Table 1: The Sustainable (Eco) innovation Output in the OECD area- Patent grants at EPO- main fields

Sustainable (eco) fields	1999-2005	2006-2011	1999-2011	Total growth
General environmental management	37.42	26.84	31.67	85.58
Energy generation from renewable and non-fossil sources	4.43	7.26	5.97	195.73
Combustion technologies with mitigation potential	2.18	1.44	1.78	78.52
Technologies specific to climate change mitigation	1.14	1.09	1.11	114.72
Technologies with potential-indirect contribution to emissions	12.43	14.94	13.80	143.42
Emissions abatement and fuel efficiency in transportation	35.58	40.90	38.48	137.15
Energy efficiency in buildings and lighting	6.82	7.52	7.20	131.42
Total sustainable (eco) patents	100.00	100.00	100.00	119,30

Source: Own elaboration of OECD patent data.

The sustainable (eco) area comprises of seven main sustainable (eco) fields, as shown in table 1. Based on that division, the above total sustainable (eco) share is mainly divided between 2 sustainable (eco) fields, namely those of the 'general environmental management' (31.67%) and the 'emissions abatement and fuel efficiency in transportation' (38.48%). The first sustainable (eco) field includes sub- fields related to 'air and water pollution abatement and management', 'waste management' and 'material recycling'. The second sustainable (eco) field includes sub- fields related to 'technologies specific to propulsion' and 'fuel efficiency-improving vehicle design'. Among the resting sustainable (eco) fields, that of 'technologies with potential or indirect contribution to emissions mitigation' accounts for 13.80%, 'energy efficiency in buildings and lighting' 7.20% and 'energy generation from renewable and non-fossil sources' concentrates the 5.97% of all patents granted by the European Patent Office during the period 1999- 2011.

Table 1 also shows that the sustainable (eco) fields differ in their growth rates. The lowest growth rate is recorded in the field 'combustion technologies with mitigation potential', while the highest in the field 'energy generation from renewable and non-fossil sources'. On the contrary, the field 'technologies specific to climate change mitigation' is similar to the OECD average.

The sustainable (eco) area is further divided into 19 sustainable (eco) sub- fields, as shown in table 2. The recorded shares show that the sub- filed 'technologies specific to propulsion using internal combustion' is ranked first concentrating the majority of patents (27.38%), followed by the 'air pollution abatement from stationary sources)' and 'water pollution abatement' and 'energy storage', which exhibit similar shares (8.93% and 8.11% respectively). On the contrary the sub- fields with the lowest shares are those of first 'heating (incl. water and space heating; air-conditioning)', second 'technologies for improved input efficiency' and third 'soil remediation', which account for less than 1% of the total sustainable (eco) patents. 'Waste management', 'fuel efficiency-improving vehicle design', 'lighting (incl. CFL, LED)' and 'renewable energy generation' are also important sustainable (eco) sub- fields with shares above 5%. The first sub- field (waste management) is further specialized in material recycling, while the forth (renewable energy generation) is further specialised in many sub- categories. Experts on this sub-field identify eight different kinds of energy generation (e.g. wind; solar thermal, photovoltaic, thermal- PV hybrids; geothermal; marine; hydro tidal, stream or damless and conventional). The analysis shows that for the OECD area the sub- field 'renewable energy generation' is further specialised to patents related to 'wind energy' and 'solar photovoltaic (PV) energy'. Finally and in relation to the sub- fields growth rates the lowest growth rate is recorded 'soil remediation', while the highest in the fields 'technologies specific to hybrid propulsion' and 'energy generation in 'renewable energy generation'.

4.2. National performance and Revealed Sustainable- Technological Advantage

Table 3 shows the sustainable (eco) innovation output in the OECD countries based on data of patent grants of the European Patent Office. Columns 4 and 6 of table 3 rank and classify the countries according to their total number of patents and sustainable (eco) patents respectively. Figures show that the OECD countries differ in their performance and innovation output in relation to the sustainable (eco) fields. Based on the total taxonomy- ranking, Slovak Republic is first (15.10%), Luxembourg is second (12.36%), Greece is third (9.93%), Japan is forth (9.18%) and Denmark is fifth (9.09%). However, the comparison between the two national rankings shows that the countries that perform better in sustainable (eco) fields are placed at the bottom of the 1st ranking (total patents), with the exception of Japan, which is classified 3rd in the 1st ranking (total patents) and 4th in the 2nd (sustainable patents). Overall, 18 countries are characterized by a better national performance in total patents and the most representative national cases in descending scale are those of Switzerland, USA (which is ranked 1st in the total ranking), Netherlands, Finland and France.

On the contrary, 14 countries are characterized by a better national performance in sustainable (eco) patents with the most important national cases those of Slovak Republic, Greece, Estonia, Czech Republic and Luxembourg. Thus, the comparative high or low national innovation output in sustainable (eco) fields doesn't seem to depend on the national economic and/or technological level, but perhaps on the national technological choices and needs: Countries with low income, comparatively less technologically developed and some of them with very severe fiscal indicators have problems seem to outperform and focus on in the sustainable (eco) area (e.g. Slovak Republic, Greece, Estonia, Czech Republic).

Column 8 of table 3 presents the total revealed sustainable- technological advantage (RSTA) at country level. The RSTA indicator shows that it ranges from 2.30 for Slovak Republic and 0.18 for Turkey. Above the value of '1' 10 European countries can be found with Japan, Canada and Australia being in the same group. On the contrary, below the value of '1' a similar number of European countries are met (12 in total) with USA, which is the most important patent holder in the OECD area.

At the sectoral revealed sustainable- technological advantage (RSTA) level seven sectoral RSTA been calculated for each OECD country. These seven indicators correspond to the seven main sustainable (eco) fields as follows: (1) RSTA for general environmental management, (2) RSTA for energy generation from renewable and non-fossil sources, (3) RSTA for combustion technologies with mitigation potential, (4) RSTA for technologies specific to climate change mitigation, (5) RSTA for technologies with potential or indirect contribution to emissions, (6) RSTA for emissions abatement and fuel efficiency in transportation and (7) RSTA for energy efficiency in buildings and lighting. Overall, the sectoral revealed sustainable- technological advantage (RSTA) at country level ranges from 23.50 for Chile in the sustainable field 'combustion technologies with mitigation potential' and 1.86 for Luxemburg in the sustainable field 'emissions abatement and fuel efficiency in transportation'.

Comparing the main sustainable (eco) fields, and in relation to the RSTA indicator, the fields 'general environmental management' and 'energy generation from renewable and non-fossil sources' are those, which concentrate the larger number of countries with a national RSTA above the respective of the OECD. On the contrary, the fields 'technologies with potential or indirect contribution to emissions' and 'emissions abatement and fuel efficiency in transportation' are those with the smaller number of countries. Overall, there is no sustainable advantage in none of the seven fields in two European countries (e.g. Italy and Slovenia). Among the countries with one sustainable advantage, this advantage can be mainly found in 'energy generation from renewable and non-fossil sources' (countries: Ireland, Israel, Spain and Turkey), and secondarily in 'combustion technologies with mitigation potential' (countries: New Zealand, Sweden and Switzerland). USA's only sustainable advantage is in 'technologies specific to climate change mitigation'

Table 2: The Sustainable (Eco) innovation Output in the OECD area- Patent grants at EPO- sub- fields

Sustainable (eco) sub- fields	**1999- 2005**	**2006-2011**	**1999- 2011**	**Total growth (%)**
Air pollution abatement (from stationary sources)	13.90	12.89	13.35	110.66
Water pollution abatement	11.23	7.00	8.93	74.40
Waste management	10.43	5.37	7.68	61.39
Soil remediation	0.97	0.38	0.65	46.52
Environmental monitoring	0.89	1.21	1.06	160.75
Renewable energy generation	3.57	6.09	4.94	203.19
Energy generation from fuels of non-fossil origin	0.85	1.18	1.03	164.51
Technologies for improved output efficiency	1.52	1.16	1.32	90.95
Technologies for improved input efficiency	0.67	0.28	0.46	50.36
Capture, storage, sequestration- disposal of greenhouse gases	1.14	1.09	1.11	114.72
Energy storage	8.06	8.16	8.11	120.68
Hydrogen production, distribution, and storage	0.82	1.21	1.03	176.76
Fuel cells	3.55	5.58	4.65	187.36
Technologies specific to propulsion using internal combustion	27.61	27.19	27.38	117.51
Technologies specific to propulsion using electric motor	2.55	4.11	3.40	192.26
Technologies specific to hybrid propulsion	1.53	3.34	2.51	261.51
Fuel efficiency-improving vehicle design	3.90	6.26	5.18	191.48
Insulation (incl. thermal insulation, double-glazing)	1.54	1.25	1.38	97.19
Heating (incl. water and space heating; air-conditioning)	0.64	0.78	0.72	146.97
Lighting (incl. CFL, LED)	4.65	5.48	5.10	140.63
Total sustainable (eco) patents	100.00	100.00	100.00	119,30

Source: Own elaboration of OECD patent data.

Table 3: Sustainable (Eco) innovation Output in the OECD area-Patent grants at EPO

OECD countries	All patents	%	Ranking	Eco-patents	%	Ranking	RTA
Australia	3080.68	0.47	17	233.50	7.58	11	1.16
Austria	7327.96	1.12	13	509.21	6.95	13	1.06
Belgium	6678.83	1.02	14	268.29	4.02	28	0.61
Canada	8032.97	1.23	12	627.40	7.81	10	1.19
Chile	35.17	0.01	28	2.00	5.69	16	0.87
Czech Rep.	356.08	0.05	25	31.50	8.85	6	1.35
Denmark	5414.81	0.83	15	492.46	9.09	5	1.39
Estonia	38.00	0.01	28	3.00	7.89	8	1.20
Finland	8208.64	1.26	11	363.08	4.42	26	0.67
France	50994.30	7.81	4	2736.11	5.37	18	0.82
Germany	148367.2	22.71	2	12295.2	8.29	7	1.26
Greece	260.08	0.04	26	25.83	9.93	3	1.51
Hungary	495.21	0.08	22	36.00	7.27	12	1.11
Iceland	109.00	0.02	27	6.00	5.50	17	0.84
Ireland	1432.81	0.22	20	50.67	3.54	30	0.54
Israel	2637.73	0.40	18	90.50	3.43	31	0.52
Italy	24312.83	3.72	7	1267.83	5.21	20	0.79
Japan	123123.3	18.85	3	11304.7	9.18	4	1.40
Korea	8841.61	1.35	10	565.75	6.40	14	0.98
Luxembourg	1127.19	0.17	21	139.33	12.36	2	1.88
Mexico	121.50	0.02	27	5.00	4.12	27	0.63
Netherlands	21132.34	3.23	8	954.46	4.52	25	0.69
New Zealand	455.54	0.07	23	17.00	3.73	29	0.57
Norway	2283.67	0.35	19	178.83	7.83	9	1.19
Poland	267.73	0.04	26	15.33	5.73	15	0.87
Portugal	275.32	0.04	26	13.00	4.72	23	0.72
Slovac Rep.	85.00	0.01	28	12.83	15.10	1	2.30
Slovenia	284.86	0.04	26	4.00	1.40	33	0.21
Spain	3873.68	0.59	16	176.67	4.56	24	0.70
Sweden	16352.15	2.50	9	779.83	4.77	21	0.73
Switzerland	25466.19	3.90	5	856.12	3.36	32	0.51
Turkey	420.92	0.06	24	5.00	1.19	34	0.18
U. Kingdom	25012.73	3.83	6	1324.12	5.29	19	0.81
USA	156639.4	23.98	1	7445.12	4.75	22	0.72
OECD area	653270.5	100.		42864.0	6.97		

Source: Own elaboration of OECD patent data.

5. Conclusions

This paper examined the production of sustainable (eco) innovation in the OECD area and for the total of OECD countries based on patent data extracted by the OECD patent database at country level. Results show that innovation in the sustainable (eco) fields account for 6.97% of the total patents granted by the European Patent Office during the period 1999-2011. Among the seven main sustainable (eco) sub- fields, those of ‘general environmental management’ and of the ‘emissions abatement and fuel efficiency in transportation’ are the most important. The former is further related to technologies of ‘air and water pollution abatement and management’, ‘waste management’ and ‘material recycling’. The latter is further related to technologies of ‘propulsion’ and ‘fuel efficiency-improving vehicle design’. Results also show that Slovak Republic is first, Luxembourg is second, Greece is third, Japan is forth and Denmark is fifth, based on the total sustainable (eco) ranking. Thus, the comparative high or low national innovation output in sustainable (eco) fields doesn’t seem to depend on the national economic and/or technological level, but perhaps on the national technological choices and needs. On the contrary, USA which is the larger patent holder based on the total number of patents is classified relatively low in the sustainable (eco) ranking, characterized by an advantage in only one field, namely that of ‘technologies specific to climate change mitigation’.

Sustainable (eco) innovation is an emerging and dynamic field, which is expected to increase its importance and its output in the near future. This increase is also due to economic, environmental, political and social factors. At economc level, such an investment can stimulate economic growth and contribute to national competitiveness. High fossil fuel prices can act as a significant damper on economic growth in countries reliant on external supply and can cause undesirable economic effects even in fossil fuel-producing countries. At the same time, industries linked to the production of sustainable innovation are also potentially significant sources of employment and income, particularly in high-wage technology sectors. At environmental level, such an investment can increase energy security, promoting the diversification of energy sources and reducing pollution and local water demand. Thus investing in non- fossil based electricity technologies could address the challenges of sustainable development and help combat climate change, which requires significant reductions in the carbon intensity of an economy. At political level, the concentration of fossil fuel resources in a relatively small number of countries provides these countries with significant political leverage over other countries dependent on the fossil fuel they supply. Diversification of energy supplies and possibly greater self-sufficiency in energy production should help insulate countries from this type of political pressure and possibly improve the global security situation. Finally, at social level, alternative energy sources can be distributed relatively equally all over the world. Thus, isolated places can benefit from the exploitation of alternative energy sources and being served cheaply and more important adequately. All these arguments justify the dynamic and of emerging importance nature of the sustainable (eco) innovation and, at the same time, confirm the need for further research in this area. This paper could be a bibliographic reference for this purpose.

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Regional sustainability efficiency indexes in Europe: An additive two-stage DEA approach

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Abstract
In this paper we apply a relational additive two-stage data envelopment analysis model in order to create sustainability efficiency indexes for European regions. The sustainability efficiency indexes are decomposed into economic and eco-efficiency indicators in the first and the second stage respectively. The economic efficiency is define as the ratio of the financial output over the inputs and the eco-efficiency is defined as the ratio of the bad output over the financial output which serves as an intermediate variable. The results reveal small inequalities among the examined regions.

Keywords: Additive two-stage DEA; Sustainability efficiency index; European regions.
JEL Codes: C14; O44; Q50

1. Introduction

Greenhouse effect is the process by which thermal radiation is absorbed by greenhouse gases from the earth's surface and it is re-emitted towards all directions including back to the earth's surface. The effect of greenhouse effect is the rising of the global temperature which is essential for the existence of the life on earth. However, a further elevation of the level of greenhouse gases due to human activities such as the burning of fossil fuels and deforestation results in global warming and climate change. The most important greenhouse gas is carbon dioxide which accounts for the 57% of the total greenhouse gases (IPCC, 2007).

The direction of past and obsolete environmental policies was the ex-post management of the environmental problems (Zofio and Prieto 2001). Instead of ex-post management, modern environmental policies should aim the prevention of environmental degradation which can be achieved by implementing sustainable development. Brundtland (1987) described sustainable development as the "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". Following the United Nations' Earth Summit in Rio in June 1992, a considerable number of countries have adopted sustainable development aspects.

Closely related with sustainable development is the notion of eco-efficiency which aims the maximization of the production while keeping the environmental degradation at the lowest possible level (Kuosmanen and Kortelainen, 2005). According to Huppes and Ishikawa (2005) eco-efficiency can be defined in four ways. At first, "*environmental productivity*" is the ratio of economic output to environmental pollution while "*environmental intensity*" is the ratio of environmental pollution to economic

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output. Furthermore, "*environmental cost improvement*" is the ratio of improvement cost to environmental improvement while "environmental cost effectiveness" is exactly the ratio of environmental improvement to improvement cost. In the present study we use the environmental intensity index.

We use data envelopment analysis (DEA) in order to construct our environmental indices. DEA assess the efficiency of decision making units which use multiple inputs to produce multiple outputs which can be measured in different units. Single-stage structures are usually sufficient for the efficiency assessment (Sexton and Lewis 2003) however in the presence of more complex structures two-stage or multistage DEA models are needed. In this paper we adopt an additive relational two-stage DEA model (Chen et al., 2009) in order to create a sustainability efficiency index which is consisted by economic efficiency in the first stage and eco-efficiency in the second stage. We apply this model to NUTS 2 regions in Belgium, Germany, France, Italy, the Netherlands, Spain and United Kingdom for 2008.

The rest of this paper is as follows: Section 2 is a review of the existing literature. Section 3 presents the methodology of the additive relational two-stage DEA model of Chen et al. (2009) and the description of the variables used in the model. The empirical application is in Section 4 and Section 5 concludes.

2. Literature review

2.1. DEA environmental indices

One controversial discussion about the specification of an environmental index is the incorporation of undesirable outputs. Traditional DEA model cannot deal with this case because it only allows for an input decrease or an output increase. However, an output decrease is not possible with the traditional DEA model. Various approaches deal with the case of undesirable outputs and here we present three of them which are most widely used.

The first approach is the weak disposability of undesirable outputs and strong disposability of inputs and desirable outputs, proposed by Fare et al (1989)[73]. This approach allows undesirable outputs to decrease if also desirable outputs are decreased proportionally. Zaim and Taskin (2000a,b) applied weak disposability to CO2 in order to measure the efficiency in OECD countries, using labor and capital as inputs and GDP as desirable output. Zofio and Prieto (2001) in a similar framework assessed the environmental efficiency in OECD countries using weak disposability on various F-gases. Other studies which used the notion of weak disposability are Arcelus and Arocena (2005), Picazo-Tadeo et al. (2005) and Zhou et al. (2006).

A second approach is to consider undesirable outputs as inputs and therefore they can be reduced towards the efficiency target[74]. This approach has been used for the cases of Dutch dairy firms (Reinhart et al., 2000), Canadian pulp and paper industry (Hailu and Veeman, 2001), Dutch sugar beet growers (De Koeijer et al., 2002) and greenhouse firms in the Netherlands (Lansik and Bezlepkin, 2003).

The third approach is to apply a monotone decreasing transformation. Lovel et al. (1995) propose the transformation of undesirable outputs into desirable ones using the outputs' reciprocals. This approach has also been used by Ramanathan (2006) who

73 Kuosmanen (2005), Färe and Grosskopf (2009), Kuosmanen and Podinovski (2009) and Kuosmanen and Matin (2011) provide an interesting discussion about weak disposability.

74 This approach has also attracted criticism about the violation of the true production process due to the use of outputs as inputs (Seiford and Zhu, 2002).

used the reciprocal of the CO_2 output in his study. Another transformation has been proposed by Seiford and Zhu (2002, 2005) which apply data translation at undesirable outputs and assumes strong disposability for all the variables including the newly transformed undesirable outputs. Data translation has also been used by Lu and Lo (2007) to study the regional development in China and Wang et al. (2014) for the needs of their two-stage DEA model. As the proper use of undesirable outputs is an open research question, we chose to use data translation because we believe it best suits the needs of our study.

Furthermore, as we already stated we use a pollution intensity index in order to measure eco-efficiency. In fact, using an environmental intensity index we allow the economy to expand without compromising the environment (Wursthorn et al., 2011). The general concept of our model is similar with Zaim (2004) who applied directional distance functions and constructed two indices. The first index is an economic index which utilizes inputs to produce economic output while the second is an environmental index which uses economic output to produce undesirable environmental outputs. Then the authors used the ratio of the two indices which is obviously a pollution intensity index. In this paper we are introducing this concept into two-stage DEA framework. A similar framework has also been used by Chen et al. (2012) however the authors study the sustainable product design of automobile industry and not environmental sustainability as in our case.

2.2. Multistage DEA models

Traditional single-stage DEA model treats the decision making unit (DMU) as a "black box" which consumes inputs in order to produce outputs without considering the internal structures. In the case of complex internal structures inside the DMU, single-stage DEA model is not sufficient, therefore multistage DEA models are needed. These models consist of more stages which are linked with intermediate variables. Färe and Grosskopf (1996) were the first to study the internal structures inside a DMU. Furthermore, pure two-stage DEA models (where all outputs of the first stage are the only inputs in the second stage) were introduced by Wang et al. (1997) and Seiford and Zhu (1999).

Two-stage models can be classified into four categories. The first category is the "*independent*" two-stage DEA model (Wang et al., 1997; Seiford and Zhu, 1999) which assess the efficiency of the two stages separately. The second category consists of connected two-stage DEA models which require both of the stages to be fully efficient in order for a DMU to be rated as overall efficient. This category includes a part of the family of network DEA models (Färe and Grosskopf, 1996) and value-chain DEA models (Chen and Zhu, 2004). The third category is the relational two-stages DEA models which include additive efficiency decomposition models (Chen et al., 2009), multiplicative efficiency decomposition models (Kao and Hwang, 2008) and network relational models (Kao, 2009; Chen et al., 2010; Cook et al., 2010a). The fourth category is about the two-stage DEA models which are based on game theoretic approaches (Liang et al., 2006, 2008). Cook et al. (2010b) and Halkos et al. (2014) provide detailed literature reviews.

We choose to use the relational additive two-stage DEA model of Chen et al. (2009) for the needs of our study. We use this model to construct environmental sustainability index.

3. Variable description and methodology

3.2. Methodology

In this section we present the VRS version of the additive two-stage DEA model. We chose variable returns to scale in order to catch any scale effects among different regions of different countries. Following Chen et al. (2009) the overall efficiency E_0 is defined in an additively:

$$E_0 = \xi_1 \cdot \frac{\sum_{d=1}^{D} w_d \cdot z_{d0} + u^A}{\sum_{i=1}^{m} v_i \cdot x_{i0}} + \xi_2 \cdot \frac{\sum_{r=1}^{s} u_r \cdot y_{r0} + u^B}{\sum_{d=1}^{D} w_d \cdot z_{d0}} \qquad (1)$$

where u^A and u^B are free in sign and ξ_1 and ξ_2 are the weights which represent the significance of each stage. Chen et al. (2009) chose not to specify the values of the weights in an a priori arbitrary way, instead they propose the weights to be calculated inside the model. Specifically, they propose the inputs of each stage as a proxy for the size of each stage. Consequently, the significance of each stage is the ratio of the size of each stage to the size of the overall process:

$$\xi_1 = \frac{\sum_{i=1}^{m} v_i \cdot x_{i0}}{\sum_{i=1}^{m} v_i \cdot x_{i0} + \sum_{d=1}^{D} w_d \cdot z_{d0}} \quad \text{and} \quad \xi_2 = \frac{\sum_{d=1}^{D} w_d \cdot z_{d0}}{\sum_{i=1}^{m} v_i \cdot x_{i0} + \sum_{d=1}^{D} w_d \cdot z_{d0}} \qquad (2)$$

By incorporating (2) in (1) and after transforming the model into a linear one, the VRS additive two-stage DEA model is as follows:

$$\max \sum_{d=1}^{D} \mu_d \cdot z_{d0} + \sum_{r=1}^{s} \gamma_r \cdot y_{r0} + u^1 + u^2 \qquad (3)$$

$$\begin{aligned}
s.t. \quad & \sum_{i=1}^{m} \omega_i \cdot x_{i0} + \sum_{d=1}^{D} \mu_d \cdot z_{d0} = 1, \\
& \sum_{d=1}^{D} \mu_d \cdot z_{dj} - \sum_{i=1}^{m} \omega_i \cdot x_{ij} + u^1 \le 0, \qquad j = 1,2,\ldots,n; \\
& \sum_{r=1}^{s} \gamma_r \cdot y_{rj} - \sum_{d=1}^{D} \mu_d \cdot z_{dj} + u^2 \le 0, \qquad j = 1,2,\ldots,n;
\end{aligned}$$

$\gamma_r, \omega_i, \mu_d \ge 0$; $i = 1,2,\ldots,m$; $r = 1,2,\ldots,s$; $d = 1,2,\ldots,D$; u^1 and u^2 are free in sign.

The decomposition of the overall efficiency in model (3) may not be unique because the optimal multipliers $\gamma_r, \omega_i, \mu_d$ may not be unique either. Kao and Hwang's (2008) proposed to maximize the efficiency for one stage, say E_0^2, while keeping the overall efficiency constant at E_0 as calculated in model (3).

$$\begin{aligned}
E_0^2 = \max & \sum_{r=1}^{s} \gamma_r \cdot y_{r0} + u^2 \\
s.t. \quad & \sum_{d=1}^{D} \mu_d \cdot z_{d0} = 1,
\end{aligned}$$

$$\sum_{d=1}^{D}\mu_d \cdot z_{dj} + \sum_{r=1}^{s}\gamma_r \cdot y_{r0} - E_0 \cdot \sum_{i=1}^{m}\omega_i \cdot x_{i0} + u^1 + u^2 = E_0,$$
$$\sum_{d=1}^{D}\mu_d \cdot z_{dj} - \sum_{i=1}^{m}\omega_i \cdot x_{ij} + u^1 \le 0, \qquad j = 1,2,\ldots,n \qquad (4)$$
$$\sum_{r=1}^{s}\gamma_r \cdot y_{rj} - \sum_{d=1}^{D}\mu_d \cdot z_{dj} + u^2 \le 0, \qquad j = 1,2,\ldots,n$$

$\gamma_r, \omega_i, \mu_p \ge 0$; $i = 1,2,\ldots,m$; $r = 1,2,\ldots,s$; $d = 1,2,\ldots,D$; u^1 and u^2 are free in sign.

Then, the efficiency of the other stage is $E_0^2 = \frac{E_0 - \xi_1^* \cdot E_0^1}{\xi_2^*}$, where ξ_1^* and ξ_2^* are the weights calculated in model (3) as demonstrated in (2).

3.2. Variable description

The data we use in our study is from 159 NUTS2 regions of seven European countries, namely Belgium, Germany, France, Italy, the Netherlands, Spain and United Kingdom. All the data was collected from OECD[75] for the year 2008. Specifically, in the first stage which from here on we will refer to as the "*economic efficiency*" stage, we use two inputs, namely capital stock and labor and one output, the GDP of each region which serves as an intermediate variable. Capital stock is not directly available, so following Feldstein and Foot (1971) and Epstein and Denny (1980) we used the perpetual inventory model: $K_t = I_t + (1- \delta) K_{t-1}$
where K_t is the gross capital stock in current year, K_{t-1} is the gross capital stock in the previous year, I_t is the gross fixed capital formation and δ is the depreciation rate of capital stock which we set at 6% (Zhang et al., 2011).

In the second stage which from here on we will refer to as the "*eco-efficiency*" stage, we use the GDP as input which is the only intermediate variable in our model and also we use CO2 as a bad output. As we already presented, we cannot use the traditional DEA models because an output expansion cannot be considered as desirable, on the contrary we desire an output contraction. From the three approaches we already presented in a previous section, we choose to apply the data translation of Seiford and Zhu (2002, 2005). Since the suitability of each model is an open research question, we chose the approach which we believe suits best with our case. According to Seiford and Zhu (2002) we transform the undesirable outputs as f(U) = -U +β where U is the vector of undesirable outputs and β is a translation vector which ensures the results to be positive, f(U)>0. Descriptive statistics are presented in Table 1.

Table 1: Descriptive statistics

	Total Labour Force	**Capital Stock**	**GDP**	**CO_2**
Mean	951	11587	62561	17826565
St. Dev.	782.2	9698	63660	17337827
Min	22.1	318	1352	4205
Max	65453	5223.1	541880	104512343

[75] Available from: http://rag.oecd.org/

4. Empirical results

We construct our sustainability efficiency index for the NUTS 2 European regions for the year 2008. We chose to give pre-emptive priority at eco-efficiency stage because our primal objective is to concentrate on the relation between economic output and environmental pressures. Thus, by solving models (3) and (4) we yield the results for the overall sustainability index, the "*economic efficiency*" index and the "*eco-efficiency*" index. All the results are presented at Table 2 along with the rankings for the overall sustainability index. In addition, Table 3 presents the average results in a country level.

A careful examination of Table 2 reveals that European regions achieve high sustainability scores, very high "*economic efficiency*" scores and good "*eco-efficiency*" scores. Furthermore, small regions tend to achieve better overall sustainability scores than large regions because the former use significantly less inputs (labor force and capital) and produce less environmental pressures (CO2). Specifically, the results from Tables 2 and 3 indicate that Belgium achieves the highest average efficiency score (0.810) and three Belgian regions (Luxemburg, Brabant Wallon and Namur) are in the top-ten regions regarding the sustainability scores. Spain and the Netherlands (0.794) are in the second place regarding the sustainability scores. Three Spanish regions (La Roja, Ciudad Autonoma de Melilla and Ciudad Autonoma de Ceuta) and a Dutch region (Zeeland) are in the top-ten achievers in sustainability scores. In the forth place is France (0.791) and Corse is the French region in the top-ten European regions. Italy and United Kingdom are in the fifth place (0.785) and two Italian regions (Valle d'Aosta, Molise) are in the top-ten regions. Germany achieves the lowest average sustainability score (0.777).

Regarding the "*economic efficiency*" the highest scores are achieved by large economic centers such as Inner London, Ile-de-France (which is the region of Paris) and Brussels and by small regions which use significantly lower inputs than others such as (Ciudad Autonoma de Melilla and Ciudad Autonoma de Cueta). Specifically, Belgium achieves the highest average economic efficiency score (0.901) and it is followed by France (0.894), the Netherlands (0.886), Italy (0.880), United Kingdom (0.877), Germany (0.874) and Spain (0.865). Regarding the "*eco-efficiency*" the highest score is achieved by Belgium (0.715) followed by Spain (0.714), the Netherlands (0.692), Italy (0.681), United Kingdom (0.677), Germany (0.662) and France (0.662). As it is clear, the "*economic efficiency*" scores are significantly higher than the "*eco-efficiency*" scores. Consequently, the decision maker should aim to improve the eco-efficiency index in order to improve the overall sustainability index. This can be achieved with an integrated common policy such as the European Sustainable Development Strategy.

The general outlook of the results reveals small inequalities among the regions relatively to their economic and the polluting activity and relatively stable average scores among countries. This might be considered as an outcome of the European Sustainable Development Strategy which was adopted in 2001 and amended in 2005 and aims the promotion of economic development with respect to social progress and environmental protection. According to Mihalcea and Verdes (2013), the idea of a common European environmental policy is to address the distortions and to implement common targets in European countries. The implementation of Sustainable Development Strategy is achieved with legislative, technical and economic instruments (Mihalcea and Verdes, 2013).

Table 2: Results for the sustainability, economic and eco-efficiency scores.

	NUTS2 Regions	Sustainability efficiency	Economic efficiency	Eco-efficiency	Rankings
Belgium	Région de Bruxelles-Capitale	0,800	1,000	0,651	34
	Antwerpen	0,770	0,875	0,650	122,5
	Limburg	0,805	0,880	0,720	30,5
	Oost-Vlaanderen	0,781	0,870	0,679	90,5
	Vlaams-Brabant	0,796	0,894	0,687	38,5
	West-Vlaanderen	0,787	0,873	0,689	56,5
	Brabant Wallon	0,847	0,923	0,766	7
	Hainaut	0,805	0,890	0,704	30,5
	Liège	0,811	0,896	0,711	23,5
	Luxembourg (BE)	0,871	0,905	0,833	5
	Namur	0,842	0,899	0,778	9
Germany	Stuttgart	0,743	0,861	0,607	149,5
	Karlsruhe	0,759	0,873	0,629	135,5
	Freiburg	0,767	0,868	0,651	125,5
	Tübingen	0,773	0,874	0,657	119
	Oberbayern	0,731	0,845	0,596	155
	Niederbayern	0,794	0,884	0,688	43
	Oberpfalz	0,787	0,872	0,689	56,5
	Oberfranken	0,810	0,889	0,696	25
	Mittelfranken	0,772	0,873	0,656	120
	Unterfranken	0,792	0,867	0,681	47
	Schwaben	0,771	0,868	0,660	121
	Berlin	0,760	0,872	0,632	134
	Brandenburg	0,767	0,837	0,661	125,5
	Bremen	0,823	0,933	0,706	15,5
	Hamburg	0,763	0,922	0,634	132
	Darmstadt	0,746	0,869	0,604	146
	Gießen	0,803	0,890	0,700	32,5
	Kassel	0,796	0,894	0,686	38,5
	Mecklenburg-Vorpommern	0,786	0,851	0,688	62
	Braunschweig	0,785	0,887	0,671	69
	Hannover	0,777	0,882	0,652	111,5
	Lüneburg	0,790	0,860	0,685	52
	Weser-Ems	0,766	0,867	0,650	127,5
	Düsseldorf	0,745	0,876	0,595	147,5
	Köln	0,749	0,869	0,611	144
	Münster	0,766	0,867	0,649	127,5
	Detmold	0,776	0,881	0,657	115,5
	Arnsberg	0,758	0,876	0,624	137
	Koblenz	0,787	0,871	0,685	56,5
	Trier	0,825	0,880	0,764	13
	Rheinhessen-Pfalz	0,775	0,877	0,660	117
	Saarland	0,806	0,897	0,698	29
	Dresden	0,777	0,856	0,685	111,5

	Leipzig	0,807	0,870	0,712	27,5
	Sachsen-Anhalt	0,776	0,851	0,663	115,5
	Schleswig-Holstein	0,763	0,867	0,643	132
	Thüringen	0,770	0,852	0,667	122,5
Spain	Galicia	0,755	0,837	0,657	140
	Principado de Asturias	0,795	0,864	0,716	41
	Cantabria	0,821	0,875	0,759	17
	País Vasco	0,765	0,866	0,649	129
	Comunidad Foral de Navarra	0,807	0,898	0,735	27,5
	La Rioja	0,843	0,881	0,799	8
	Aragón	0,779	0,855	0,690	103
	Comunidad de Madrid	0,724	0,833	0,592	156
	Castilla y León	0,753	0,832	0,659	142,5
	Castilla-la Mancha	0,757	0,843	0,682	138
	Extremadura	0,799	0,851	0,737	35,5
	Cataluña	0,720	0,828	0,590	158
	Comunidad Valenciana	0,733	0,825	0,622	154
	Illes Balears	0,785	0,853	0,706	69
	Andalucía	0,721	0,816	0,605	157
	Región de Murcia	0,774	0,836	0,701	118
	Ciudad Autónoma de Ceuta	0,995	1,000	0,984	2
	Ciudad Autónoma de Melilla	1,000	1,000	1,000	1
	Canarias	0,763	0,834	0,677	132
France	Île de France	0,796	1,000	0,546	38,5
	Champagne-Ardenne	0,783	0,868	0,686	80
	Picardie	0,780	0,873	0,674	96,5
	Haute-Normandie	0,782	0,884	0,667	87
	Centre	0,781	0,872	0,649	90,5
	Basse-Normandie	0,783	0,865	0,689	80
	Bourgogne	0,783	0,876	0,676	80
	Nord - Pas-de-Calais	0,785	0,897	0,628	69
	Lorraine	0,781	0,865	0,659	90,5
	Alsace	0,782	0,886	0,665	87
	Franche-Comté	0,786	0,858	0,702	62
	Pays de la Loire	0,786	0,897	0,630	62
	Bretagne	0,785	0,889	0,638	69
	Poitou-Charentes	0,783	0,878	0,676	80
	Aquitaine	0,786	0,893	0,635	62
	Midi-Pyrénées	0,786	0,886	0,642	62
	Limousin	0,803	0,886	0,737	32,5

	Rhône-Alpes	0,793	0,943	0,595	45
	Auvergne	0,787	0,869	0,692	56,5
	Languedoc-Roussillon	0,785	0,874	0,655	69
	Provence-Alpes-Côte d'Azur	0,792	0,926	0,610	47
	Corse	0,885	0,988	0,816	4
Italy	Piemonte	0,743	0,854	0,613	149,5
	Valle d'Aosta	0,910	0,980	0,863	3
	Liguria	0,791	0,898	0,672	50
	Lombardia	0,718	0,845	0,567	159
	Provincia Autonoma Bolzano/Bozen	0,819	0,927	0,735	19
	Provincia Autonoma Trento	0,820	0,918	0,745	18
	Veneto	0,737	0,849	0,606	153
	Friuli-Venezia Giulia	0,789	0,881	0,686	53
	Emilia-Romagna	0,741	0,855	0,608	151
	Toscana	0,754	0,867	0,624	141
	Umbria	0,813	0,890	0,721	22
	Marche	0,788	0,885	0,678	54
	Lazio	0,739	0,861	0,599	152
	Abruzzo	0,794	0,875	0,701	43
	Molise	0,867	0,911	0,819	6
	Campania	0,748	0,850	0,628	145
	Puglia	0,764	0,865	0,646	130
	Basilicata	0,836	0,892	0,774	11
	Calabria	0,784	0,865	0,691	73,5
	Sicilia	0,753	0,855	0,634	142,5
	Sardegna	0,784	0,863	0,692	73,5
The Netherlands	Groningen	0,824	0,942	0,700	14
	Friesland	0,816	0,890	0,733	20
	Drenthe	0,833	0,898	0,757	12
	Overijssel	0,792	0,884	0,689	47
	Gelderland	0,769	0,868	0,655	124
	Flevoland	0,823	0,875	0,781	15,5
	Utrecht	0,780	0,881	0,666	96,5
	Noord-Holland	0,756	0,873	0,623	139
	Zuid-Holland	0,745	0,858	0,614	147,5
	Zeeland	0,841	0,913	0,762	10
	Noord-Brabant	0,759	0,868	0,634	135,5
	Limburg	0,794	0,888	0,688	43
United Kingdom	Tees Valley and Durham	0,778	0,864	0,706	107
	Northumberland and Tyne and Wear	0,778	0,862	0,681	107
	Cumbria	0,809	0,870	0,761	26
	Cheshire	0,785	0,906	0,687	69
	Greater	0,777	0,871	0,640	111,5

	Manchester				
	Lancashire	0,777	0,859	0,683	111,5
	Merseyside	0,779	0,852	0,694	103
	East Yorkshire and Northern Lincolnshire	0,785	0,871	0,715	69
	North Yorkshire	0,791	0,883	0,716	50
	South Yorkshire	0,780	0,856	0,691	96,5
	West Yorkshire	0,777	0,863	0,650	111,5
	Derbyshire and Nottinghamshire	0,777	0,878	0,656	111,5
	Leicestershire, Rutland and Northamptonshire	0,779	0,883	0,661	103
	Lincolnshire	0,796	0,861	0,743	38,5
	Herefordshire, Worcestershire and Warwickshire	0,780	0,861	0,686	96,5
	Shropshire and Staffordshire	0,778	0,860	0,683	107
	West Midlands	0,780	0,878	0,639	96,5
	East Anglia	0,780	0,874	0,644	96,5
	Bedfordshire and Hertfordshire	0,781	0,895	0,655	90,5
	Essex	0,779	0,875	0,669	103
	Inner London	0,791	0,961	0,573	50
	Outer London	0,786	0,916	0,608	62
	Berkshire, Buckinghamshire and Oxfordshire	0,783	0,894	0,627	80
	Surrey, East and West Sussex	0,783	0,891	0,630	80
	Hampshire and Isle of Wight	0,780	0,888	0,653	96,5
	Kent	0,780	0,873	0,674	96,5
	Gloucestershire, Wiltshire and Bristol/Bath area	0,783	0,887	0,636	80
	Dorset and Somerset	0,783	0,864	0,690	80
	Cornwall and Isles of Scilly	0,811	0,860	0,771	23,5
	Devon	0,783	0,852	0,702	80
	West Wales and The Valleys	0,779	0,865	0,680	103
	East Wales	0,786	0,870	0,689	62
	Eastern Scotland	0,783	0,877	0,648	80
	South Western Scotland	0,783	0,878	0,647	80
	North Eastern Scotland	0,815	0,927	0,729	21

	Highlands and Islands	0,799	0,829	0,774	35,5
	Northern Ireland (UK)	0,782	0,882	0,670	87

Table 3: Average scores in a country level

	Sustainability efficiency scores		**Economic efficiency scores**		**Eco-efficiency scores**	
Countries	mean	st.dev	mean	st.dev	mean	st.dev.
Belgium	0.810	0.031	0.901	0.037	0.715	0.056
Germany	0.777	0.022	0.874	0.019	0.662	0.036
Spain	0.794	0.079	0.865	0.052	0.714	0.113
France	0.791	0.022	0.894	0.038	0.662	0.036
Italy	0.785	0.047	0.880	0.033	0.681	0.076
Netherlands	0.794	0.033	0.886	0.023	0.692	0.057
UK	0.785	0.010	0.877	0.023	0.677	0.043

5. Summary and concluding remarks

We use the additive two-stage DEA model (Chen et al., 2009) in order to create a sustainability index for NUTS 2 regions in seven European countries, namely Belgium, Germany, Spain, France, Italy, the Netherlands and United Kingdom for the year 2008. Regarding the first stage, we construct an "*economic efficiency*" index which utilizes inputs (labor and capital) to produce GDP which serves as the only intermediate variable in our model. Regarding the second stage, we construct an "*eco-efficiency*" index where GDP is the only input and CO2 is the only undesirable output. The resulting index of sustainability is considering both economic and environmental aspects and is in line with the concept of sustainable development, thus expanding the economic output without compromising the environment.

The results reveal high results for the overall sustainability index, very high results for the "*economic efficiency*" index and good results for the "*eco-efficiency*" index. From a decision maker point of view, the regions have greater potential to improve their "*eco-efficiency*" scores in order to improve the overall sustainability scores. Furthermore, the results indicate small inequalities among the regions relatively to their economic and the polluting activity. However, in an average country level the results seem to be relatively stable. These relatively uniform results might be result of the European Sustainable Development Strategy which aims to address the distortions and to implement common targets in European countries. Some interesting aspects for future research would be to extend our analysis to include more environmental pressures and also a bigger time horizon.

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Environmental policies and eco-innovation

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Abstract
Eco-innovation is often presented as a response to environmental regulations and as a solution to overcome problems related to the environmental as well as the economic crisis. What is still debated is whether regulations have the potential to foster or to block innovation and more specifically eco-innovation. There are policies with the aim to solve environmental problems through innovation, but the obstacles that may arise during this process are not few. In this paper we are going to examine the most common environmental policies that countries use and whether they are effective enough to foster firms to adopt eco-innovation. We propose a categorization of certain policy instruments to market pull and technology push. We examine the conditions under which policies may act as motivations to eco-innovation.

Keywords: Eco-innovation; environmental regulations; environmental technology; innovation barriers.
JEL Codes: Q00, Q4, Q5

1. Introduction

Considering the environmental damage that the previous generations, including ours, have caused it is undoubted that sustainable use of resources and processes that produce less pollution and bring about less damage are necessary. Governments and local authorities seek to raise awareness of the issue and to compel citizens, firms and whole industries to develop and adopt eco-innovations.

Eco-innovation is defined by Kemp & Foxon (2007), as the production, assimilation or exploitation of a product, production process, service, management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resource use (including energy use) compared to relevant alternatives. Hemmelskamp (1997) defines 'eco-innovation' as an innovation that has as its target to prevent or reduce anthropogenic burdens on the environment, clean up damage already caused or diagnose and monitor environmental problems.

Triguero et al. (2013) distinguish the drivers that lead to eco-innovations in three types, shaped by supply side factors, by demand side factors or by environmental policies. By supply side they mean that innovations take place because there are technological or management capabilities, or because firms have better access to information and knowledge and as a result end up with an opportunity to develop new technologies or to save substantial amounts by adopting eco-innovations. By demand side they mean that demand for green products and the rise in market share are factors that invite firms to adopt eco-innovations. Finally, environmental policies, more specifically existing and expected regulations and the access to subsidies and fiscal incentives, entail regulatory push and pull to adopt environmental innovations.

Still, the adoption of eco-innovations is neither straightforward neither easy, due to a variety of barriers. Governments try to conquer these barriers by deploying policies intended to act as market pull instruments, technology push instruments or as regulatory push/ pull instruments. Here we propose a categorization of such policies.

The paper is organized as follows: the role of the selection environment in this process is presented in Section 2. In Section 3 describes the barriers that are met by entrepreneurs during the adoption process. Section 4 presents the environmental policies and the way they are structured so as to be effective and efficient.

2. The role of the Selection Environment

Malloy (2004) points out that the process to catalog every factor that affects technology choice is neither feasible nor useful. He suggests focusing on a small set of socio-economic factors first termed by Nelson and Winter as the "selection environment". The selection environment is a small set of socio-economic factors that play a significant role in technology choice and as a consequence it can determine the fortune of an eco-innovation. Nelson and Winter (1982) state "that the selection environment is determined partly by conditions outside the firms in the industry or sector being considered product demand and factor supply conditions, for example but also by the characteristics and behavior of the other firms in the sector." The selection environment, "also includes the mechanisms by which information about the innovation flows to potential adopters; the attributes of the innovation and its value to the potential adopters (i.e., the benefits and costs of adoption); and the strength of pre-existing routines and behaviors exhibited by relevant individuals and organizations." (Malloy 2004: 4)

The regulatory obligations and constraints that a firm faces are of critical importance and part of the selection environment. But a very important part of the selection environment is also the mechanisms of diffusion to potential adopters of information about the innovation, the attributes of the innovation and its value to the potential adopters, along with the background of pre-existing routines and behaviors exhibited by relevant individuals and organizations. By analyzing and understanding the selection environment regulatory designers can detect systemic barriers to innovation, identify regulatory alternatives that would specifically address those barriers, and anticipate how the system will likely respond to the various alternatives.

Based on Nelson and Winter's analysis (1982), a general model of the selection environment may be devised by "specification of the following elements : (1) the nature of the benefits and costs that are weighed by the organizations that will decide to adopt or not to adopt a new innovation ; (2) the manner in which consumer or regulatory preferences and rules influence what is "profitable"; (3) the relationship between "profit" and the expansion or contraction of particular organizations or units; and (4) the nature of the mechanisms by which one organization learns about the successful innovations of other organizations and the factors that facilitate or deter imitation." (Nelson and Winter, 1982, pp.262-263)

According to Hoevenagel et al. (2007) the selection environment is characterized by five factors, which are pressure, interest, surroundings, information and benefits. By pressure they refer to the extent that governmental measures increase the pressure on enterprises. Interest denotes the extent that governmental measures increase awareness and alertness to environmental issues. Surroundings refer to the extent that governmental measures leverage the professional surroundings of enterprises relevant to adopting environmental technologies. By information they refer to the extent that governmental measures increase the flow of information about environmental technologies to firms. Finally, benefits from the adoption of new eco-friendly technologies are also conditioned by the selection environment. For example, most compelling factors in the case of eco-innovation could be pressure, how much are entrepreneurs obliged by the law or by specific environmental regulations to adopt eco-innovations, and benefits, e.g. tax credits.

3. Barriers in the adoption process

The barriers that may arise in the adoption process of eco-innovation are an integral part of the selection environment. Here we propose a categorization of them into institutional/organizational, techno-economic, functional, psychological and temporal.

Institutional and organizational barriers refer to issues such as the existence of more than one conflicting regulations, unclearly defined or focused regulations, the fact that there are uncertainties about the new regulations and as a consequence misunderstandings arise and firms get cold feet to proceed to an eco-innovation adoption, or lack of information about a specific regulation and to difficulty to coordinate among companies.

Techno-economic barriers include the cost that the adoption of eco-innovation or lack of sufficient funding, the incompatibility of new technology with existing production processes or regulations, the lack of proper information about new technologies and lack of qualified personnel.

As functional barriers, Druehl et al. (2011) identify usage, value and risks. New innovations require changes to the user's mode of operation that may be perceived at the beginning as inconvenient, difficult, or slow to use. Risk refers to the fact that the new innovation is unknown to the user and entails uncertainty. There are 4 types of risk: physical which means that the new technology may cause harm, economic i.e. loss of money or inferior performance, functional because sometimes people or organizations do not have the ability to adjust their performance properly, and social risk which involves people's tendency to follow other people's choices (peers' view). Economic risk is also associated with fear of the product becoming obsolete or the next generation being substantially better or concern that current investment will prove insufficient. The risk barrier includes uncertainty and contributes to the delay of innovation diffusion and adoption. Last, the value barrier refers to the performance-to-price index compared to substitutes. Each user assigns a different factor of gravity various aspects of performance. The possibility to adopt an eco-innovation depends on the price of the eco-innovation and the necessity to adopt this or a substitute of this.

Psychological barriers, that may play compensatory role in the process of adopting an eco-innovation, include tradition and image. Tradition pertains to the fear of change in daily routine, habits, customs, and social norms. Potential adopters of the new innovations may be afraid to adopt it as they believe that it is going to change their routines, affect their relationships, status or organizational politics. Image refers to the opinion that the public has about a certain eco-innovation and the difficulty to convince what is better and more efficient and effective, compared to the ones that are already in use.

Temporal barriers rise due to the restrictions caused by the short time that regulations allow firms in order to choose an eco-innovation among the available ones and to adopt the eco-innovation they have selected. This barrier usually leads firms to select the best available technology (BAT) at the moment as they do not have the time to develop a new more fitting to the situation or to search and wait for a better solution that may exist or may be launched soon.

Table 1 below summarizes a considerable number of the barriers that may arise during the adoption process of eco-innovation as discussed above. In order to overcome these barriers governments try to set environmental policies and use policy instruments so as to make the consequences more attractive to entrepreneurs.

Table 1: Barriers met at the eco-innovation adoption process

Institutional/ Organizational	Techno-economic	Functional	Psychological	Temporal
Conflict between regulations Unclear scope of regulations Lack of mechanisms to explain regulations Uncertainties over new regulations Difficulties to coordinate with other companies Lack of information about regulations	High cost Lack ofinternal funds Lack of financial support Existence of dominant enterprises Lack of qualified personnel Lack of information about new technology Incompatible technology to existing production process or to regulations	Risk/ Uncertainty Usage Value	Tradition Image	Short time restrictions to address regulations Short time restrictions to adopt innovations

Source: Own processing, based on Cleff et al. (2007), Rothwell (1980), Druehl, et al. (2012) and Hezri (2011)

4. Environmental policies and eco-innovation

We examine the types of the regulations (including incentives/motives), their targets and under which condition may they have the expected results. As Kemp (2012) states "different types of eco-innovation require different policies. Incremental improvements of commercial products rarely need special support, as firms are normally able to produce and fund these. By contrast, radical and system innovations need much more support, especially radical transformative innovations. So, i advocate strong support for transformative innovation, embracing not only financial but also institutional change in the economic and social world."

Environmental regulations are government legislation (laws, acts, directives) as well as standards and industry commitments that have as their target to contribute to the reduction of environmental burden and resource consumption (Renning and Rammer, 2010). It must be conceded that the primary aim of environmental regulation is to protect the environment and not to stimulate technological change, but the two are by no means incompatible, as the quest of the first is served by the latter.

According to Porter and Van der Linde (1995a, b), the main aims of environmental regulations are: to create pressure and make firms innovate

to improve the quality of the environment, to alert and educate companies about opportunities and threats they will face, to inform industries that innovation is environmentally friendly, to create demand for environmental improvement and to level the playing field during the transition period. Ashford et al. (1985) group regulations into five types, depending on whether they: require demonstration of product safety prior to marketing, require demonstration of the efficacy of products prior to marketing, require proof of safety or the control of product use after marketing, control production technology to reduce risks to workplace health and safety and control emissions, effluents, or wastes.

The first category refers to products like pesticides, food additives, pharmaceuticals and new chemicals. It refers to the regulations that aim to preserve a high level of safety of a product for the environment, biodiversity and human beings. The second category refers to regulations that affect products like pharmaceuticals. Efficacy of medicines has to be known before their consumption. The third type of regulations refers to products that contain substances such as chemicals with known attributes; their aim is to assure that they remain safe for workers, consumers and the environment. The fourth type refers to regulations that control workplace technology. The last type is regulations about raw materials that firms use and aim to reduce or contain the emissions and the effluents produced.

From case to case what may also vary, with the aim of better results, is the form of the regulation that is applied. Environmental regulations may take many forms, along different directions and from different actors or sources:

New environmental regulation can be met by a variety of means, with perhaps the two main options being basic process change or end-of-pipe effluent control. The first approach will require innovation and might even lead to the development of radical new processes. The second approach will also require innovation, but in this case the innovation will generally derive from equipment suppliers outside the regulated industry. (Rothwell, 1992: 450)

4.1 How should policies be designed?

Porter and Van der Linde (1995b) suggest that the introduction of environmental laws and regulations should take place in three phases: firstly phrase environmental rules as goals that may be met in flexible ways as needed; secondly encourage innovation to reach and exceed those goals; and finally administrate the system in a coordinating way. Above all regulators have to consider the technological capabilities and resources available to each stage so as to be more accurate in the goals that they set and to make sure that even though difficult, they are realistically feasible.

Jaenicke (2007) and Leitner et al. (2010) suggest that governments should concentrate on "smart" regulations, i.e. policy instruments that have a positive effect both on environment and innovation and therefore lead firms to sustainability. "Smart" regulations are often more efficient and effective in achieving environmental goals and stimulate companies to view environmental issues as a business challenge and opportunity. Smart regulations, according to Jaenicke (2007), play also a very important role in the political competition for environmental innovation and are also sometimes identified as a key force that leads to environmental regulation. Leitner et al. also believe that environmental innovation is a means that can certainly contribute to shifting society towards sustainable development. They support that there is a need for systematically improved environmental regulation as well as environmentally motivated innovation policy.

On another note, Hezri states: "The 'shift' towards sustainable development requires an institutional change, and one which requires a long-term perspective." (Hezri, 2011: 59) So, what is necessary is not only changes in technology, but in regulations and in institutions as well, so as to have the desired results. This, however, requires time to be accomplished. According to Herzi (2011), in order to achieve the necessary institutional changes, generic principles should be adopted by governments and adapted so as to suit varying contexts: governments have factor in the long term, which means that sustainable development addresses elements operating over decades and centuries, governments have to adhere to integrating environment, society and economy in policy; in other words that sustainability refers to the interactions between the three pillars and government has to take responsibility for the environmental and social implications of economic policy, governments have to follow the precautionary principle which requires recognition of uncertainty, encourages proactive rather than reactive policy actions and shifts the onus of proof from those concerned about the environmental effects of policies and developments to those advocating development, governments have to take into account the global dimensions, as sustainable development is a global issue. This is needed as international concern and policy developments have generally outstripped domestic policy in both intent and vigor. Innovative policy approaches are needed, given the complexity of sustainable development problems and the implementation deficit so far. We have to focus on the factor of community participation; community-based programs tend to be poorly resourced, switched on and off according to near term government agendas, lacking a clear mandate and a set of responsibilities, and at times they seem to be more about cost-shifting and delegation of implementation tasks than sharing of knowledge and power.

The time that is needed to formulate a regulation is not short and regulators have to take into account several important things such as the existing technological capacity when it comes to eco-innovations, and also the capital cycle of firms that are supposed to adapt this regulation. According to OECD, 'What appears to be more important is how the formulation period is used: if it contributes to a sustained process of consultation with industry, it can have a positive effect; lf it provides for an erratic and unpredictable procedure to take place, companies ready to respond innovatively can suffer'. (Rothwell, 1992: 453)

According to Ashford et al. (1985), regulators have to take into consideration the process of technological change within the possible responding sectors as well as, the "innovative dynamic" of the sector rather than the existing static technological capacity. Regulators should also take into account the effects that their policies will have on technological innovation. On the same issue, Porter and Van der Linde (1995a, b) believe that the designing of regulations depends on the goals that each government sets, and as innovation foster consists one of the regulations goals, they claim that regulations have to adhere to three principles:

1. regulations have to create the appropriate environment so as to reach the maximum opportunity for innovation,
2. regulations have to foster continuous improvement in technology and
3. last but not least, regulations must not leave a huge room for uncertainty at every stage of innovation and adaptation of new technology by the firms.

Wiser and Pickle (1998) claim that policy design should be linked with incentive mechanisms to policy goals, subject to technical, market, and financial constraints. But, this does not usually happen and additionally to political considerations and lack of information, it has as a consequence during the development of policies mismatches between a policy's incentive mechanism and technical, market, or financial constraints. Also, lack of information, as it is mentioned in Murage et al. (2011), is a factor that affects the adoption speed of the innovations. More specifically, Hall et al. (2011) refer to the situations, in which information may not be enough so as to choose the correct next step. They believe that "innovation is thus a knowledge quest and creation process, requiring the reduction of uncertainty." (Hall et al., 2011: 1146) They concur with Knight that there are varying degrees of imperfect information, like: true risk, where key interacting variables and outcome probabilities are known, uncertainty, where variables are known but not probabilities, and what has since been termed Knightian uncertainty or ambiguity, where variables and probabilities are unknown.

Del Río et al. (2010) suggest that if a policy will be able to influence the rate and direction of eco-innovations, policy makers should be well informed about the barriers that could hinder eco-innovation. As Wiser and Pickle (1998) mentioned, what affects policy effectiveness is that designers usually ignore or misunderstand the project development and the financing process that is going to be followed. Grubb and Ulph (2002) point out that if policymakers wish to encourage firms to introduce cleaner technologies, what is necessary is to use a combination of environmental and technology instruments. A very important factor that policy makers have to be aware of is the selection environment of an eco-innovation. As Malloy (2004) states "an understanding of the selection environment allows policymakers to do three things: detect systemic barriers to innovation, identify regulatory alternatives that would specifically address those barriers, and anticipate how the system will likely respond to the various alternatives." As a consequence knowing the selection environment helps to face some predictable barriers more efficiently.

4.2 Environmental policy instruments

Policies used by governments have either penalizing or encouraging character. Penalizing instruments are usually taxes and other charges to firms in order to restrain the pollution they cause and encouraging are usually policies that give a motivation to firms to adopt an eco-innovation.

Usually penalizing instruments constitute high charges on the firms' activities, internalizing external costs. These charges may cause firms to innovate in order to reduce pollution levels and of course the amount that they would have to pay and might stimulate innovation and growth in companies producing pollution control equipment. In addition, Jaenicke (2007) argues that the growing business risk for the polluters can become another driving force of "ecological modernization". One of the negative economic instruments can be to fund pollution control via pollution charges, as Rothwell (1992) mentions. In this way financial resources will be provided to laboratories so as to examine how they can control pollution, in accordance with the polluter pays principle (PPP) (polluters, governments or consumers are these who have to pay the effects of technology on the environment, on social life and on peoples' health). From the opposite side, this is referred to as the way by which firms can buy the "right" to pollute.

Pollution taxes perform as incentive to polluters to reduce emissions and to look for alternative technologies (OECD 2011). According to the OECD (2011), environmental taxation is more effective in comparison with regulations, because regulations just set emissions limits or prescribe the use of other technologies while taxation encourages both the lowest cost abatement across polluters and provides incentives for abatement at each unit of pollution. However, as Rennings (2000) claims, the innovation efficiency of taxes may be watered down by the political process and that is why under political stability we have higher efficiency.

As innovation is a process that costs a lot and also is considered to be of high risk by the investors, governments have also established some encouraging instruments so as to reach the targets that they have set. An instrument that is adopted so as to promote the adoption of new technologies and more specifically the technologies that foster renewable energy is Feed-in-Tariffs (FIT). Feed-in tariffs (FITs) are generation-based, price-driven incentives. A feed-in tariff is a way that was invented to motivate people, businesses and everyone that is interested in renewables to invest in it. Feed-in tariffs oblige energy network operators to buy electricity produced by renewable resources at a fixed price, usually over a fixed period.

The EU also uses Quota Obligations, as an instrument to foster eco-innovation (Resch et al. (2007). Quota obligations based on Tradable Green Certificates (TGCs) are generation-based, quantity-driven instruments. A system which involves renewable energy quotas and tradable renewable certificates works as follows: quota is imposed on one category of electricity system "operators" (generators, producers, distributors, retailers, or consumers) to cover produce, supply or consumer/purchase at a certain percentage of electricity from renewable energy sources (RES-E). As a consequence a TGC system, under perfect market conditions (perfect price signals), can minimize generation costs for renewable energy sources.

Comparing the two instruments above a feed-in tariff has many advantages over a quota system. It offers certainty and guarantees for investors, it is transparent, easy to administer, it promotes diversity of supply and it is flexible.

Many countries help the firms or the individuals that want to adopt eco-friendly innovations to proceed to an investment in eco-innovation through financial subsidies. Ringel (2006) points out a negative aspect of subsidies, as they do not always work well. Subsidies may have negative impacts, the most important one being the weakening, as most of the times subsidies do not refer to all the innovative products but to some specific ones. For example, many countries have specialized in one or two renewable sources, according to local and national geographical conditions, but these technologies are not always subsidized by the organizations. And this has sometimes as a consequence the promotion of most profitable solution and not the optimal one.

Another strategy to promote eco-innovation is covenants (Kemp 2000). Covenants are contracts between an industry or an industrial sector and government in which industry promises to progressively reduce the environmental burden of its activities within a certain period (often five to ten years) according to certain targets. We may say that this is a strategy that Europe has adopted in our days regarding its target to reduce the emissions by 20% and also increase the use of energy produced by alternative sources to 20% by 2020.

We can also see that Europe tends to support not only the process of adoption of innovation but also of its diffusion. The EU has started an initiative called Eco-innovation that has as a target to bridge the gap between research and the market. As the European Commission states: "It helps good ideas for innovative products, services and processes that protect and help the environment have fully-fledged commercial prospects, ready for use by business and industry. In doing so, the initiative not only helps the EU meet its environmental objectives but also boosts economic growth." The target of the Eco-innovation initiative is to develop products, techniques, services and processes that reduce CO_2 emissions, use resources efficiently, promote recycling and so on. This initiative has five strands: Materials recycling and recycling processes, Sustainable building products, Food and drink sector, Water efficiency, treatment and distribution and Greening business.

In Table 2 above we summarize some of the most recently met policies. A very important issue is which policy can be assigned as a "response" to which barrier. We may say that Feed-in-tariffs are a very strong "weapon" in order to convince firms/industries to adopt eco-innovations. This is why this policy instrument produces a climate of safety as they will not have the uncertainty of failure or of not reaching depreciation of the investment. Quota obligations are also a policy instrument that can create climate of safety as firms are sure that a certain amount of goods derived by eco-innovation are requested.

Table 2: Policy instruments encouraging or forcing innovation

Instrument	Aims	Intended impacts	Results	Factors	Type of instrument
Feed-in Tariffs (FIT)	Make firms/ people invest on RES (solar, wind energy)	Increase the % of electricity generated by RES	The capital cost of solar PV has fallen substantially	Falling technology costs, risk of high expanding PV	Market pull
Quota Obligations	Reach the target of energy produced by renewables	To minimize the cost of generating renewable electricity	Increase demand for renewable electricity	A fair distribution of costs and benefits of RES implementation	Market pull
Covenants	Reduction in energy use	Substitute environmentally hazardous substances	Foster technological innovation	Autonomous technological change, external regulations and evolution on the market demand	Technology push
Eco-innovation	Help ideas to become feasible and protect the environment	Bridge the gap between research and the market	Many eco-innovation projects already running	SMEs have priority in getting in the Eco-innovation project	Technology push
Polluter Pays Principle (PPP)	Make firms reduce their emissions	Reduce Greenhouse Gas emissions	Polluters pay for the damage they have caused	We have to know who has rights to use the resources	Market pull
Environmental taxes	Level the playing field in the electricity markets	Make businesses to adopt new technologies	Internalize external cost	Political stability	Market pull

Source: Own processing, based on Cleff et al. (2007), Rothwell (1980), Druehl, et al. (2012) and Hezri (2011)

Environmental taxes and PPP may be a motivation for firms to overcome the barrier of investment high cost and lack of funds. Firms may prefer to invest in an eco-innovation instead of paying huge amounts in taxes for the pollution they cause and may take into account the fact that the new investment would also renew their capacity. Covenants on the other hand may be the way to overcome the temporal barriers as they are giving time to firms to commit to changes within a particular period of time. Eco-innovation programs facilitate to overcome the barriers of lack of information about new technology and of incompatible technology to existing production process or regulations as its aim would be to encourage the development of new technology and of relevant standards and specifications.

Finally, the timing and sequence of policy measures should be taken into account during policy design. A typical example of a motivating program was an EU funded program that took place in Greece aimed at households and companies. This program provided investment subsidies for changes in their houses or in their premises having as aim to reduce their energy consumption. However the program was not combined with other policy measures. Neither a comprehensive information campaign nor – most importantly – did an eco-innovation development program took place. An alternative could be to shift the funds from subsidies for eco-innovation adoption to eco-innovation development and provide other incentives, such as property tax-breaks timed a few years later. In this way there would be a market creation mechanism that would also reduce risk for eco-innovators.

5. Conclusions

In the introduction of this paper we analyze the content of eco-innovation and the difficulties that firms face during the adoption process. We categorize barriers in five categories organizational/institutional, techno-economic, functional, psychological and temporal. Often the barriers that a firm faces are combination of two or more barriers of different categories. In order to deal with these barriers and compel firms to proceed to eco-innovation adoption governments apply policies of different types. These policies may be of encouraging or penalizing character. Policies of encouraging character are subsidies and technology push policies like covenants, while penalizing policies may be taxes and policies like polluter pays principle.

Policies need to be structured; the most important factor for a policy to be effective is to take under account the capabilities of the industry or sector that it is addressed to and to create the appropriate environment so as to persuade firms to adopt an eco-innovation. The two main incentives that induce eco-innovation are regulations that have environmental sustainability as a target and the cost saving that firms are going to enjoy after the eco-innovation adoption. Finally, the timing of policy measures and their sequence are critical parameters of policy design, in order to accrue the synergies that would deliver most benefits in terms of environmental, innovation and economic impact.

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The impact of social capital on willingness-to-pay for hard engineered coastal defences in south-east England

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Abstract

Globally, one of the most common approaches to protect coastal areas from flooding and erosion is to construct hard engineered defence structures. However, it is now widely acknowledged that constructing and maintaining 'hard' defences is both financially and environmentally challenging for public authorities and national governments. Here we seek to investigate the willingness of residents in rapidly eroding coastal zones facing flooding risks to contribute towards the costs of maintaining and constructing such structures. Our analysis examines the influence of social capital parameters on respondents' willingness to pay, which have been identified as influential in recent studies. Fieldwork was conducted in Romney Marsh, south-east England, a low-lying coastal area experiencing adverse impacts from sea level rise that are expected to escalate in future under current climate change projections. The study found 45.6% of respondents were willing to pay an average monthly premium of £3.53 to subsidise coastal defence expenditure. Our study demonstrates that generalised and particularised forms of trust clearly exert a positive influence on WTP, which could be used by policy actors to enhance and possibly to increase public acceptability in cases where financial contributions are likely to be requested in future from the public by government. On the other hand, the fact that social networks function in a negative way indicates that policy makers should contribute to discussion and debate in local social networks and explore how information influences citizens' perceptions positively and negatively.

Keywords: Sea defences; protest responses; trust; networks; Romney Marsh.

JEL classification: Q54; Q48.

1. Introduction

Planning policies for coastal management due to climate change impacts is a difficult and challenging task. A variety of factors should be taken into consideration when planning and implementing such policies including environmental and socio-economic issues (Halsnaes & Traerup, 2009; Mearns & Norton, 2010). This is because coastal management policies are often accompanied from significant opposition from local communities resulting to conflicts between locals and management actors (Apine, 2011; French, 2006; Roca & Villares, 2012; Roth & Warner, 2007; Myatt et al., 2003).

One way of minimizing social conflicts and increasing social acceptability of proposed coastal management policies is the investigation of social impacts and citizens' potential reaction prior to policy implementation (Jones & Clark, 2013). This type of investigation is even more important when a financial burden on citizens is considered by policy-makers, such as a users' tax. One way of exploring such issues is to estimate the Willingness to Pay (WTP) of citizens for the maintenance and construction of defences in order to protect their property and the natural environment surrounding them. Some studies have been presented aiming to evaluate willingness to pay of citizens in the wider field of climate change mitigation (Longo et al., 2012; Solomon & Johnson, 2009).

Also, literature has been recently developed exploring WTP for making changes in homes in order to protect them from flooding and also for the estimation of insurance cover (The Consumer Council, 2013; Botzen et al., 2013). However, to our knowledge, very limited studies attempt to estimate how much citizens would be willing to pay in order to increase or reconstruct sea defences on coastal areas (e.g. Landry et al., 2011). Furthermore, apart from exploring the intention and willingness of individuals to pay, it is equally important to explore the factors that determine citizens' valuation.

The present paper aims to contribute to this discussion by exploring the WTP of individuals for the construction and maintenance of sea defences and analysing the impact of social factors, focusing mainly on social capital, on this specific evaluation. In order to examine the above issue we selected as a case study the area of Romney Marsh in South-East England. The specific area faces significant impacts from climate change which are expected to escalate in the future. In the next section we will briefly identify the main links between social capital and WTP before presenting the methods and results of our research.

2. Methods

2.1 Description of the research area

In order to investigate WTP for the construction and maintenance of sea defenses, an empirical survey through the distribution of a structured questionnaire was conducted. The area were the questionnaire was distributed was Romney Marsh (South-East England). The main reason for selecting the specific case study was because it currently faces impacts from climate change which are expected to significantly increase in the next years (Shoreline Management Plan, South Foreland to Beachy Head, 2006). Romney Marsh is a reclaimed land and the majority of it is under sea level. Due to the specific geomorphology of the area, a potential flooding incident on the coast could result to extended flooding in the marsh. For this reason, strong defenses have been built in several parts of the coast. The current management plan proposes to continue maintaining these defenses. However, in order to continue maintaining the current defenses and constructing new ones, there is a high need for further funding.

Questionnaires

The total sampling frame of the area was 22,000 households and a sample of 1000 households was selected through random sampling processes. The response rate was 16% resulting to 160 usable questionnaires. A questionnaire was created aiming to investigate citizens' perceptions on climate change, their opinion on a proposed coastal management policy and to explore certain social factors, connected mainly with trust and networks, in the area.

Specifically, on coastal management issues, a hypothetical policy was presented to respondents which is similar to the one currently applied with the only exception that citizens would have to contribute financially directly through a tax. Specifically, respondents were asked to suppose that as a community they have the following option:

to maintain the current coastal defenses and construct new ones wherever it is necessary in order to minimize the impacts from climate change. Participants were also informed that these new defenses were going to be partly funded by a new governmental tax. The WTP question was then presented asking if they would you be willing to pay an amount per month as a household through this new tax. For those respondents who replied positively, a payment card with four options was presented to them which is regarded an efficient technique to elicit reliable estimations in CVM (Blaine et al., 2005; Solomon & Johnson, 2009) (£1, £3, £5, £7). An open-ended choice was also available to respondents in case they wanted to state a different amount from the ones proposed.

Furthermore, regarding the social factors questions, four main parameters were investigated which are commonly explored in the literature: a) institutional trust, b) social trust, c) participation in social networks and d) social norms (Woolcock &Narayan, 2000; Jones et al., 2012).

2.2Data analysis

Data were analysed through the use of SPSS 21.0 statistical software. The estimated through a non-linear function WTP amount was based on three distinct samples: in the first estimation we included all WTP responses of the sample. In the second estimation we excluded those answers that we regarded as 'protest responses' retaining in the final estimation only the 'true zeroes'. Specifically, respondents who refused to pay due to financial constraints or due to low personal valuation were considered 'true zeroes' (e.g. protection from flooding is not important to them) (Afroz et al., 2009). All other justifications, such as objection to the policy or payment vehicle, were considered as protest responses. A third evaluation of WTP was based on a sample including only the positive responses on WTP.

In order to explore the influence of factors on WTP we conducted an exploratory factor analysis (EFA) to reduce dimensionality of the initial explanatory variables in the questionnaire and of which connection to the WTP is to be tested. . Specifically, EFA reduced the initial independents to a total of 7 latent constructs combining risk perceptions (RISK, Cronbach a: 0.934), benefits for the proposed policy (BENEFITS, a: 0.743), disadvantages of the proposed policy (DISADVANTAGES, a: 0.716), trust in institutions (INST TRUST, a: 0.777), trust in other people (SOCIAL TRUST, a: 0.859), participation in social networks (NETWORKS, a: 0.682) and the two questions referring to social reciprocity (SOCIAL RECIPROCITY, a: 0.884). The seven extracted factors were added to the rest of the observed items including: demographic characteristics (gender, age, educational level, income level, owner of property in the area), concern on climate change (CONCERN), how serious they consider the impacts of climate change on global (GLOBAL) and local (LOCAL) level, the level of awareness for the proposed policy (AWARE) and whether they think that this approach will protect them from flooding (PROTECT). They were all subsequently entered as predictors for the WTP estimation. Specifically, three multiple generalized linear regression models (GLMs) were utilized for the estimation of WTP based upon the three samples described previously, namely a GLM where only positive WTP responses are included in the analysis, a GLM analysis including only the "true zeros" and finally we fitted a GLM including only positive WTP responses as the dependent. GLM analysis is a suitable approach since it provides us the advantage of simultaneously including as independents both continuous and categorical variables.

3. Results

3.1 Descriptive analysis of the data

Perceptions for climate change and the proposed coastal management policy. According to the preliminary analysis of the selected sample, a mean score of 3.4 (maximum values: 5, st. dev (d.v.): 1.25) was presented regarding the level of concern for climate change. Furthermore, respondents were more concerned for the impacts of climate change in the area of Romney Marsh (mean: 3.9/5, s.d.: 1.18) compared to the impacts on global level (mean: 3.42/5). Regarding risk perceptions 'water shortage' and 'deterioration in water quality' were the two most important risks for respondents. The least important risks were 'rising temperatures' and also 'soil erosion'.

Regarding citizens' perceptions for the management policy presented to them, 51.9% of the sample declared that they are aware of it. Furthermore, the same percentage of respondents stated that they regard that this approach can protect them from flooding in the future. Finally, on a 5 point Likert scale, respondents presented a mean score of 3.6 (s.d.=0.93) for their level of agreement for the proposed policy. Concerning the benefits of the proposed policy (all measured in 5 point Likert scale with higher values representing higher importance), the most important were connected with 'protection of properties/houses' (mean: 4.49, s.d.: 0.78) and 'protection of agricultural lands' (mean: 4.33, s.d.:0.95). Lower scores were presented for 'Protecting biodiversity' (mean: 3.9, s.d.: 1.10), 'retaining public access to beach' (mean: 3.56, s.d.:1.12) and 'maintenance of recreation activities' (mean: 3.3, s.d.:1.23). Regarding the disadvantages, there were no differences between their evaluation as they all presented a similar mean score ('tax burden on citizens': mean 3.55, s.d.: 1.36; 'high maintenance cost': mean: 3.66, s.d. 1.23; 'possible biodiversity loss', mean: 3.63, s.d.: 1.15).

Social factors

Regarding the level of institutional trust, specifically for coastal management issues, the highest levels of trust were presented for the Environment Agency (mean: 5.94, s.d.: 2.71), followed by Natural England (mean: 4.66, s.d.: 2.77) and local councils (mean: 4.59, s.d.: 2.6). Lower scores were presented for the remaining institutions (European Union: mean: 2.19, s.d.: 1.64, National government: mean: 3.38, s.d.: 2.21, Local NGOs: mean: 3.75, s.d.: 2.26, DEFRA: mean: 4.43, s.d.: 2.44). All variables were measured on a 10 point Likert scale with higher values representing higher levels of trust. Regarding generalized trust a mean score of 4.63 (s.d.: 2.28) was presented. This was increased when investigating particularized trust towards neighbours (mean: 5.79, s.d.: 2.65) and people of the local community (mean: 5.67, s.d.: 2.15). When the level of trust was specified towards the local community for managing coastal management issues a mean score of 4.4 (s.d.: 2.54) was presented.

In addition, concerning fairness, the mean score for the sample was 4.99 (s.d.: 2.42). Concerning social networks, 31% of the sample declared that they are a member in at least one NGO and of these 18.4% stated that their membership is in an environmental NGO. Furthermore, 9.6% stated that they are a volunteer in at least one NGO and from these 8.9% is in an environmental NGO. 17.1% declared that they have participated in local community groups and only 4.4% have participated in some coastal defence action group in the area. Finally, regarding social reciprocity, 82.3% of the respondents declared that they believe that their neighbours will help them if their home was in danger of flooding. This percentage if increased when this help is from family and close friends (88.5%).

3.2 Willingness to Pay

Regarding the WTP question, respondents were asked to state whether they would be willing to pay an amount for the construction and maintenance of defences through a local tax which would be paid monthly by households in their area. According to the study 53.1% of the sample declared a negative answer (45.6% stated that they would be willing to pay some amount). Willingness to pay was estimated in three different ways. Initially, WTP was measured for all respondents, including all zero responses. A second estimation included only those who declared a positive answer. In a final estimation, we calculated all responses excluding protest responses. In the first case where all responses were included, the mean WTP was approximately £2/month (Table 1). By excluding protest responses this amount increases to £3.52. Finally when estimating WTP only from positive responses, this is £4.46 (Table).

Table 1: Willingness to pay

	N	Minimum	Maximum	Mean	Std. Deviation
All responses	160	0	10.00	2.01	2.69
Positive and true zeroes responses	91	0	10.00	3.53	2.71
Only positive responses	72	1.00	10.00	4.46	2.26

Econometric analysis: Factors influencing WTP through GLM regression analysis

We conducted GLM analysis in order to explore the potential factors influencing WTP. Our main focus was on social factors and also on variables measuring perceptions for coastal management issues. We estimated WTP based on three samples according to responses on WTP (GLM1: All responses, GLM2: excluding protest responses and GLM3: only positive responses). Generally, there were three variables which influenced WTP in all of the fitted models. These were the income level, how serious respondents consider the current impacts of global climate change and the aggregate measurement of risk. All these variables influenced WTP in a negative way.

More analytically, the estimated coefficient parameters for each independent variable of the three GLM derived models are shown in Table 2 along with the associated significance (p-values). Estimates for the non-statistically significant explanatory variables are not shown due to word limitations.

Table 2: Parameter estimates for the three GLM models

	GLM 1 all responses		**GLM 2 true zeros**		**GLM 3 positive responses**	
Predictor	**Parameter Estimate**	**p-value**	**Parameter Estimate**	**p-value**	**Parameter Estimate**	**p-value**
Constant	4.624	n.s.	2.388	n.s.	-2.934	n.s.
INST TRUST	1.513	0.002***	1.651	0.001***	--	--
SOCIAL TRUST	1.351	0.024**	1.151	0.019**	--	--
NETWORKS	-1.184	0.002***	-0.835	0.075*	--	--
RECIPROCITY	-21.728	0.054*	--	--	-49.966	0.003***
BENEFITS	--	--	--	--	--	--
DISADVANTAGES	--	--	--	--	--	--
RISKS	-0.903	0.085*	-1.395	0.032**	-2.371	0.037**
CONCERN Reference category: very						
Not at all	--	--	7.155	0.083*	--	--

2	--	--	1.822	n.s.	--	--
3	--	--	1.224	n.s.	--	--
4	--	--	1.562	n.s.	--	--
GLOBAL Reference category: very						
Not at all	-2.293	n.s.	-10.603	0.031**	-8.076	0.006***
2	-6.619	0.012**	-10.809	0.003***	-5.854	n.s.
3	-1.048	n.s.	3.942	0.042**	-4.602	0.008***
4	-2.077	n.s.	-3.184	0.033**	-2.053	n.s.
LOCAL Reference category: very						
Not at all	-0.326	n.s.	3.453	n.s.	--	--
2	1.338	n.s.	5.823	0.002***	--	--
3	-5.337	0.003***	-1.816	0.098*	--	--
4	-4.1	0.008***	-2.979	0.014**	--	--
AWARE Reference category: yes						
no	--	--	1.891	0.018**	2.603	0.005***
PROTECT Reference category: yes						
no	--	--	--	--	-2.737	0.057*
AGREEMENT Reference category: totally agree						
disagree	-3.468	0.018**	--	--	--	--
Neither agree nor disagree	-0.399	n.s.	--	--	--	--
agree	-0.855	n.s.	--	--	--	--
OWNER Reference category: yes						
no	--	--	--	--	6.908	0.017**
EDUCATION	--	--	--	--	-0.144	0.095*
AGE	--	--	0.063	0.049**	--	--
INCOME Reference category: >£70,000						
≤£12,000	0.381	n.s.	-2.563	n.s.	-5.723	0.035**
£12,001-£30,000	-0.005	n.s.	-1.665	n.s.	-3.411	n.s.
£30,001-£70,000	-3.987	0.037**	-5.022	0.001***	-6.035	<0.001***
R^2	0.785	(R^2 adjusted: 0.564)	0.954	(R^2 adjusted: 0.843)	0.977	(R^2 adjusted: 0.899)

(*) Coefficient is significant at a 10% significance level
(**) Coefficient is significant at a 5% significance level
(***) Coefficient is significant at a 1% significance level
n.s.: non-significant
Dependent Variable: Amount of willingness to pay for coastal defences

We observe from the results of Table 2 that in the first model including all respondents, in addition to the three items found statistically significant in all fitted models, the seriousness of the current impacts of climate change in Romney Marsh is also statistically significant (with a negative sign) along with the level of agreement with the proposed policy (highest level of agreement results to lower economic valuation). Furthermore, all social capital variables have a statistically significant influence on WTP. Citizens with higher levels of social (beta coefficient=1.351, p-value<0.05) and institutional trust (beta coefficient=1.513, p-value<0.01) are more willing to pay while citizens with higher involvement in social networks and higher sense of reciprocity are less willing to pay. Finally, citizens who tend to perceive lower risks are also less willing to pay based on the model where all responses are included (GLM1).

When exploring the model where only positive responses and true zeroes were included (GLM2), apart from income, seriousness of climate change impacts on global level and risk perceptions, additional factors were found to have a statistically significant effect on WTP. Specifically, how serious individuals consider the current impacts of climate change in the area of Romney Marsh is an influential factor. Furthermore, the level of awareness of the proposed approach is positively connected with WTP (individuals who know the policy are more willing to pay). Regarding social capital parameters, institutional trust and social trust are both positively associated with WTP while social networks and risk perceptions are negatively associated. Finally, age is positively associated with WTP (beta=0.063, p-value<0.05). This means that older individuals (age was measured through year of birth) are more willing to pay for the defences in the area, at least when considering the specific respondents' group.

Finally, in the last model where only the positive responses are included, apart from the three common factors mentioned above, we found additional different factors which influence WTP. Specifically, reciprocity - found to be non significant in the other two models - influences negatively WTP (beta=-49.966, p-value<0.01), accompanied also by the educational level of the participant (beta=-0.144, p-value<0.1). Furthermore, awareness of the proposed policy has a positive influence on WTP while the idea that this approach will protect them from sea level rise is connected with WTP in a negative way. Individuals who tend to think that it is not an efficient policy are WTP more money from the construction and maintenance of the defences.

As concerns model fit, the model's R^2 value including all WTP responses is 0.785 (R^2 adjusted: 0.564), whereas the fit of the other two models was found to be considerable better [GLM2 R^2: 0.954 (R^2 adjusted: 0.843); GLM3 R^2: 0.977 (R^2 adjusted: 0.899)] indicating that through the selected items we have managed to explain a large part of the variance in the answers of respondents on their WTP.

4. Conclusions

The findings of the present study are very important taking into consideration the limited funds that currently exist for the construction of sea defences. Although other type of softer mitigation and adaptation policies can be applied, in some cases the maintenance of this type of constructions is essential, due to the high value of a community concerning social, economic and environmental aspects. Consequently, it is possible that in the future, communities will be asked to contribute financially in order to be protected from climate change impacts. In the case of Romney Marsh, the average WTP was estimated to £3.53 per month. A positive influence of trust on WTP was presented which could be used by management actors in a positive way in order to increase public acceptability in case financial contribution is requested from the public.

An indicative example, is the participation in the deliberation techniques of all actors including those which are most trusted by the public (such as the EA) and at the same time those who are least trusted in order to increase the level of trust towards them (e.g. national government). On the other hand, the fact that social networks function in a negative way indicates that policy makers should investigate the information that flows on local social networks and explore which information influences citizens' perceptions in a negative way. The application of such techniques is essential in order to understand the reaction of local communities and incorporate their knowledge and opinions in policy planning processes. Such efforts would significantly increase the level of social acceptability for coastal management policies, necessitating the financial contribution of citizens.

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Implementing the European Water Framework Directive in Greece: An Integrated Socio-Economic Approach and Remaining Obstacles

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Abstract

The implementation of the EU Water Framework Directive (WFD) in Greece has faced several challenges that range from technical problems to complex institutional issues. In order to understand such challenges, the evolution of EU water-related directives and regulations are examined in this chapter. The reasons that explain Greece's difficulties with the implementation of the WFD are outlined. A methodology that allowed the rapid assessment of the *status quo* of the water situation on each of the fourteen Greek River Basin Districts is also presented. The results show that the current pricing policy requires changes in order for the water bodies to reach good ecological status and to ensure full recovery of the cost of water services. Most importantly, the results highlight the difficulties in the implementation of this 'scientific knowledge intensive' EU Directive and the challenge it constitutes for Southern European countries with weak institutional structure and limited financial resources.

Keywords: EU WFD; Asopos River Basin; Water quality; Cost recovery; Water Pricing.

Introduction

The purpose of the EU Water Framework Directive (WFD) is to establish a common framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater in order to prevent further deterioration and to enhance the status of aquatic ecosystems. Hence, achieving "good status" for all waters by 2015 is one of its key objectives (EC 2000). Each Member State is responsible for the implementation of this Directive (adoption of implementing measures before a specified deadline, conformity and correct application) within its own legal system. Three main steps for the implementation of the WFD can be identified: 1) setting of ecological standards, 2) identification of anthropogenic pressures and 3) adoption of corrective measures. However, the implementation of the WFD in Greece has faced several challenges that range from technical problems to complex institutional issues. The Commission of the European Communities is responsible for ensuring that EU law is properly applied.

Thus, if a Member State fails to comply with EU law, the Commission has powers of its own to try to bring the infringement to an end and, where necessary, may refer the case to the European Court of Justice. The European Commission has referred Greece to the EU Court of Justice a number of times for failing to take measures to guarantee that different water related Directives are correctly applied. In order to understand the requirements and challenges in implementation of the WFD in Greece the evolution of the different water-related directives and regulations will be analysed in this chapter. Then, we will move on to describe the situation of the water sector in Greece.

In the context of a legal action of 'Non-Conformity' started by the EC against Greece (case C-264/07), the reasons for not catching up fast enough with the implementation of the WFD will be outlined. The following issues will also be discussed: a) a methodology that enables rapid assessment of the status quo of the water situation in each Greek catchment and (b) the implementation of this methodology on each of the fourteen Greek River Basin Districts (RBDs) and related outcomes. As it will be explained in the following sections, it is evident that reforms in the current pricing policy are required in order for the water bodies to reach good ecological status and to ensure full recovery of the cost of water services. In general, it can be expected that Southern European countries with weak institutional structure and limited financial resources will face further difficulties during the implementation of the WFD.

1. The Evolution of European Legislation on Water Resources

In this section, we analyse how the European Legislation on Water Resources has evolved in the last fifty years. This is important to understand the requirements and challenges in implementation of the Water Framework Directive in Greece. In the literature it is widely acknowledged that the evolution of European legislation and policies for water resources has gone through three different waves (see Kallis and Nijkamp 2000, CEC 2000, Kaika 2003, Dworak *et al* 2006, and REC 2008). Table 1 shows the Directives passed in each of the three waves of European legislation on water resources. In the following sections each of the three waves will be presented and analysed.

1.1 Early European Environmental Legislation and First Wave of European Legislation on Water Resources

The first wave of legislation started with the launch of the First Environmental Action Programme (EAP) 1973-1976 (OJ C 112, 20.12.73). This early European environmental legislation established the objectives and principles of the environmental policies of the European Commission (EC). The programme was mainly concerned with water protection and waste emissions and comprised a special reference to agriculture and spatial planning (Hey 2005 and Dworak *et al* 2006). In consequence, a number of Directives were enacted in order to reduce and prevent water pollution based primarily on a regulatory approach. For example, the Directive on Water Pollution by Discharges of Certain Dangerous Substances (76/464/EEC) was one of the first water related Directives to be decreed. Its aim was the regulation of impending water pollution by chemicals produced in Europe at that time. The concepts of list I and list II substances were introduced for the first time in the Annex of this Directive.

Pollutants included in list I include substances regarded as particularly dangerous on the basis of their persistence, toxicity and bioaccumulation. Pollutants in list II included substances that are considered less dangerous but which, nevertheless, can have a deleterious effect on the aquatic environment (Horth *et al* 2003). The Directive covered discharges to surface waters, coastal waters and groundwater. The protection of groundwater was removed from the Directive (76/464/EEC) and a new Directive on the protection of groundwater against pollution caused by certain dangerous substances (80/68/EEC) was established (CEC 2000). In general, two different approaches to tackle water pollution at European Level have been used: the water quality objective approach (WQO) which defines the minimum quality requirements of water to limit the cumulative impact of emissions, both from point sources and diffuse sources. This approach was mainly used in the first wave of water directives. On the other hand, the emission limit value approach (ELV) was mainly used in the second wave of water legislation during the 1990s and focuses on the maximum allowed quantities of pollutants that may be discharged from a particular source into the aquatic environment (REC 2008).

Table 1: The Three Waves of European Legislation on Water Resources

Early European water policy	
1973	First Environmental Action Programme (EAP) 1973-1976 (OJ C 112, 20.12.73)
First Wave of Legislation	
Focus on water quality objectives (WQO)	
1975	Surface Water Directive (75/440/EEC)
1976	Bathing Water Directive (76/160/EEC)
1976	Directive on Water Pollution by Discharges of Certain Dangerous Substances (76/464/EEC)
1978	Fish Water Directive (78/659/EEC)
1979	Shellfish Water Directive (79/923/EEC)
1980	Directive on the protection of groundwater against pollution caused by certain dangerous substances (80/68/EEC)
1980	Drinking Water Directive (80/778/EEC)
Second Wave of Legislation	
Focus on emission limit value approach (ELV)	
1991/1998	Urban Waste Water Management Directive (91/271/EEC and 98/15/EEC)
1991	Nitrates Directive (91/676/EEC)
1996	Directive for Integrated Pollution and Prevention Control (96/61/EC)
Third Wave of Legislation	
Integrated approach	
1996	Commission's Communication on European Water Policy (COM(96)0059 - C4-0144/96)
1997	Commission's Proposal for a Water Framework Directive (COM(97) 49)
1997	Commission's amended proposal following consultation (COM(97) 614)
1998	Commission's further amendment of proposal following consultation (COM(98) 76)
2000	Water Framework Directive (WFD) (2000/60/EC)
2006	New Bathing Water Directive (2006/7/EC)
2006	Groundwater Directive (2006/118/EC)
2007	Floods Directive (2007/60/EC)
2008	Marine Strategy Framework Directive (MSFD) (2008/56/EC)
2008	Directive on Environmental Quality Standards (Directive 2008/105/EC)
2009	Directive on the Sustainable Use of Pesticides (2009/128/EC)
2010	Industrial Emissions Directive (2010/75/EU)

Source: Adapted from Kaika (2003), Dworak et al (2006) and EC (2012b)

1.2 Second Wave of European Legislation on Water Resources

In the first half of the 1990s, the increasing eutrophication of the ocean and the deteriorating state of water resources were considered the major water related problems within the EU. The second wave of European legislation started in 1991 and occurred after a review of the existing regulations and the identification of gaps and required improvements. In this second wave the Directives defined quality standards, which had to be achieved through certain measures for controlling emission levels (Kaika 2003 and Dworak *et al* 2006). Two new Directives were adopted and set stringent rules on the treatment of wastewater and the use of nitrates in agriculture: The Urban Waste Water Management Directive (91/271/EEC and 98/15/EEC) established legally binding measures at community level in order to regulate the collection and treatment of urban waste water and the discharge of industrial waste water from the agro-food industry. On the other hand, the Nitrates Directive (91/676/EEC) complements the Urban Waste Water Directive by reducing and preventing the nitrates pollution of water from agricultural sources (chemical fertilizer and livestock manure), to protect drinking water supplies and to prevent eutrophication (Dworak *et al* 2006). Other relevant amendments were done in the Drinking Water and Bathing Water Directives (in 1994 and 1995 respectively), in order to update them. Further, in 1994 a proposal for an ecological quality of water Directive was drafted (REC 2008).

1.3 Third Wave of European Legislation on Water Resources

The third wave of European water legislation started in 1996. A communication of the European Commission on water policy of the Community (COM(96)0059 - C4-0144/96) was published on February that year. This document concluded that in order to improve the efficiency of water protection legislation a Water Framework Directive was required (CEC 1996). After four years of analysis and negotiations, the WFD was passed by the EU's Parliament in September 2000 and came into force in December 2000 (Kaika 2003). The aim of this directive is to achieve good ecological status of all waters by 2015. In contrast to the previous waves of legislation, the area covered by this Directive extends to all aquatic systems, surface waters (rivers and lakes), groundwater and coastal waters. The WFD meant a radical shift to measure quality of all waters using a range of biological communities rather than the more limited aspects of chemical quality (REC 2008 and Moss 2008).

The Directive (2007/60/EC) on the assessment and management of flood risks entered into force on 26 November 2007. Its aim is to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity. It requires that Member States to prepare flood risk maps in order to assess the extent and assets and humans at risk in relevant areas and to take adequate and coordinated measures to reduce this risk. The Marine Strategy Framework Directive (2008/56/EC), was published in the Official Journal of the European Union the 17th of June 2008. It states that pressure on natural marine resources and the demand for marine ecological services are too high. Thus, its main goal is to achieve good environmental status of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend. The Groundwater Directive (2006/118/EC) is a WFD daughter since groundwater protection should be tackled separately (see WFD Article 16). It was passed by the European parliament on the 12th of December 2006 and entered into force on 16 January 2007. The Directive aims to prevent the pollution of groundwater from agricultural residues such as pesticides and other harmful substances (REC 2008).

2. The Water Framework Directive

As established in its first Article, the purpose of the WFD is to establish a common framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater in order to prevent further deterioration and to enhance the status of aquatic ecosystems and to contribute to mitigating the effects of floods and droughts (EC 2000). One of the key objectives of the Directive is to achieve good ecological status for all waters by 2015, and preserving such status where it already exists. The Directive classifies ecological status of aquatic habitats on a scale from high (effectively pristine) to bad and includes intermediate steps of good, moderate and poor. The concept "good ecological status" implies that water can be used as long as the ecological function of the water body is not significantly impaired (Moss 2008 and REC 2008).

The WFD recognizes the need to approach the interaction of anthropogenic activities and water resources in an integrated approach in order to attain sustainable water resources management. It should be noted that the WFD combines the two approaches to pollution control previously discussed: ELVs and WQOs. Both are used to mutually reinforce each other and in any particular situation, the more rigorous approach is applied (Kaika 2003 and REC 2008). In particular, the WFD establishes in its Article 10 that all Member States shall ensure the establishment and/or implementation of emission controls based on best available techniques, or relevant emission limit values (ELV), or in the case of diffuse impacts the controls including, as appropriate, best environmental practices described in the water related directives (e.g. the Urban Waste Water Management Directive (91/271/EEC and 98/15/EEC) and the Nitrates Directive (91/676/EEC)) and any other relevant Community legislation.

Thus, the WFD provides an integrated framework for water resources management and protection in Europe, both in terms of quality and quantity to achieve the objective of good ecological status (EC 2000). Further, the role of economics in reaching environmental and ecological objectives is explicitly acknowledged in this Directive and requires the application of economic principles, approaches, tools and instruments at River Basin District (RBD) level. Public participation in decisions is also required.

In addition, since the 2015 deadline to achieve good water status in all water bodies the use of disproportionate cost analysis in terms of extended deadlines and less stringent environmental objectives (Esteban, Le Quesne, and Strosser 2006). Article 4.4 establishes that an extension to the 2015 deadline is permitted if "completing the improvements within the timescale would be disproportionately expensive" and article 4.5 states that "Member States may aim to achieve less stringent environmental objectives for specific bodies of water when they are so affected by human activity…or their natural condition is such that the achievement of these objectives would be infeasible or disproportionately expensive" (EC 2000:10). On the other hand, it should be noted that Article 9 states that Member States "shall take account of the principle of recovery of the costs of water services, including environmental and resource costs, having regard to the economic analysis conducted according to Annex III, and in accordance in particular with the polluter pays principle" (EC 2000:12). The environmental cost reflects social welfare losses associated with water quality deterioration, caused by the water uses, while the resource cost represents additional costs required to cover water demand under water deficits due to the overexploitation of available water resources. Furthermore, the WFD also states that the cost recovery of water services should be analyzed for different water uses, which should be at least disaggregated into households, industry and agriculture. Table 2 shows the disaggregation of the total cost of water services.

Table 2: Total Economic Cost of Water

Financial Cost	Costs of providing and administering water services: capital cost, operation cost, maintenance cost and administrative cost.
Environmental Cost	The environmental cost represent the costs of damage that water uses impose on the environment and ecosystems and those who use the environment (e.g. a reduction in the ecological quality of aquatic ecosystems or the salinization and degradation of productive soils).
Resources Cost	Resource cost represents the costs of foregone opportunities which other uses suffer due to the depletion of the resource beyond its natural rate of recharge or recovery (e.g. linked to the over-abstraction of groundwater).

Source: Koundouri, Kountouris and Remoundou (2010)

3. Challenges in the Implementation of the Water Framework Directive

The implementation of the WFD has faced several challenges. Almost all EU Member States have spent substantial resources to develop tools, to gain the required data and to prepare River Basin Management Plans (RBMPs) by 2009 as required under Article 13 (Moss 2008). According to the Commission's Compliance Report (EC 2007), one of the main deficiencies in the WFD implementation is the economic assessment. According to Annex III of the Directive, the economic analysis reports should contain adequate information on the major drivers and pressures in each RBD and on the contribution of water uses in the recovery of costs consistent with the polluter pays principle, to enable the selection of the program of measures on a cost-effectiveness basis (EC 2000). Even though all EU Member States sent country reports in accordance to Article 5, half of them did not supply information at all on cost recovery. This reflects the informational and methodological difficulties that Member States face when implementing the economic elements of the WFD. The European Commission has taken Belgium, Denmark, Greece and Portugal to court over their failure to comply with EU water legislation and submit plans for managing their river basins.

These plans should have been adopted by 22 December 2009 at the latest. Besides, according to the Report from the Commission to the European Parliament on the implementation of the WFD, the assessment of the RMBPs "shows the poor quality of the assessment of costs and benefits. A strong improvement in this area and the definition of a shared methodology for the calculation of costs (including environmental and resource costs) and benefits (including ecosystem services) is necessary. Otherwise, it will be possible neither to ensure the implementation of effective pricing policies nor to avoid disproportionate and inadequate measures" (EC 2012a). Finally, according to Article 9 of the Directive, by 2010 Member States should have introduced pricing policies and economic instruments with the element of cost-recovery for the environment's benefit. However, "there are very few Member States that have implemented a transparent recovery of environmental and resource costs. Cost recovery is implemented, to a greater or lesser extent, in households and industry. For agriculture, in many areas, water is charged only to a limited extent" (EC 2012a). When available, cost-recovery levels vary significantly. Member States that have provided information on households have indicated a cost recovery rate of services for households between 70 and 100%. For industry, the Member States providing information reported a cost recovery rate between 40 and 100%. For agriculture the cost recovery rate is reported to vary between 1 and 100% (WWF, 2006).

Therefore, the EC (2012a) report suggests to the EU Member States to improve cost-benefit assessment to ensure cost-recovery and to ensure the transparency and fairness of water pricing policies. Some recent reviews on the implementation of water pricing in Europe reach similar conclusions. Despite the guidelines provided by the WFD and the general consensus about the importance of cost recovery and incentive pricing for an effective water policy, tariff designs and price levels between EU Members and even between RBDs remain largely heterogeneous (EEA 2013 and EC 2012c). In the agricultural sector (and despite its importance as water user) a significant portion of water abstractions is not priced and the recovery of the operation and maintenance costs of water services remains limited: "In more than one third of the Member States, farmers do not pay for their water abstractions." (EC 2012c:45). This phenomenon is prevalent in water stressed Southern European Member States.

4. The water situation in Greece and the implementation of the EU WFD

The political and administrative structures in Greece can be described as hierarchical and centralized with institutions dependent mainly on the state and the political parties. There is little participation of the civil society and lack of agreements among political elites. The central government determines the planning and the allocation of resources, considerably limiting the participation of other actors to provide wider legitimization. In consequence, the introduction of participatory arrangements required for the implementation of different European policies (including the WFD) has been very difficult (Demetropoulou *et al* 2010). In the late 1980s emerged the first attempts to decentralize and to include integrated and participatory forms of water governance at water basin level with Law 1739/87 "for the Management of Water Resources." Its main goal is the reservation of adequate water supply to satisfy the present and future demand for different water uses and defined and established procedures and structures that permitted water management on a national and a regional scale (Sofios *et al* 2007 and Demetropoulou *et al* 2010). Greece has an area of 131.957 km^2 and was divided into 45 River Basins (RB) (see figure 1) and grouped into 14 River Basins Districts (see figure 2).

Figure 1: Greek River Basins

Source: http://www.minenv.gr/nera/ (WFD Article 3 report - Greek maps)

Figure 2: Greek River Basin Districts

01: West Peloponnese	06: Attica	11: East Macedonia
02: North Peloponnese	07: East Sterea Ellada	12: Thrace
03: East Peloponnese	08: Thessaly	13: Crete
04: West Sterea Ellada	09: West Macedonia	14: Aegean Islands
05: Epirus	10: Central Macedonia	

Source: http://www.minenv.gr/nera/ (WFD Article 3 report - Greek maps)

The Law 3199/2003 integrated the WFD into the national legislation of Greece (MoEPPW, 2003). In Greece, water supply, waste water collection, treatment and disposal are public services. However, the top-down approach of policy-making and implementation is prevalent and the coordination between the different governmental levels has remained incoherent (Demetropoulou *et al* 2010). In Athens and Thessaloniki, water companies controlled by the Ministry of Environment Physical Planning and Public Works own and operate the treatment plants on a non-for profit basis. In other cities, water supply is managed by municipal companies operating as private enterprises DEYA (Municipal Enterprise for Water Supply and Sewerage) but owned by the municipalities. Each DEYA determines its pricing policy on the basis of their cost and is approved by the Municipal Council. The mean price per cubic meter of water in Greece is estimated at €1.27. Irrigation water prices are set based on private cost criteria. 40% of Greece's abstraction and distribution of irrigation water is provided by Local Irrigation Companies and the mean price per irrigated thousand square meters is €13.73 (Koundouri et al 2014).

Table 3 shows the most significant water uses in each RBD. The demand of water for residential use was calculated taking into account the resident population (200 litres person/day) in each RBD and all the nights of tourists spent in each region (300 litres person/night since the flow of tourists is higher in summer) according to the 2001 census. The highest demand of water for residential use was found in Attica. Not surprisingly, this RBD also has the biggest population. The demand of water for irrigation was calculated taking into account crop needs of water. Then, based on the cultivation area of each crop species in each RBD, the water demand was estimated. The highest demand of water for irrigation was found in Thessaly. The water requirements for industrial use were calculated according to data on water consumption in Industrial Areas. The highest demand of water for the industry was found in Central Macedonia.

Table 3: Economic analysis of water uses and pressures in each RBD

River Basin District	Population (2001)	Area (km^2)	Demand for residential use (hm3 /year)	Demand for irrigation (hm^3 / year)	Demand for industry (hm3 /year)
1. West Peloponnese	331 180	7 301	23	201	3
2. North Peloponnese	615 288	7 310	36.7	395.3	3
3. East Peloponnese	288 285	8 477	22.1	324.9	0.03
4. West Sterea Ellada	312 516	10 199	22.4	366.5	0.35
5. Epirus	464 093	10 026	33.9	127.4	1
6. Attica	3 737 959	3 207	400	99	1.5
7. East Sterea Ellada	577 955	12 341	41.6	773.7	12.6
8. Thessaly	750 445	13 377	69	1,550	0.054
9. West Macedonia	596 891	13 440	43.7	609.4	30
10. Central Macedonia	1 362 190	10 389	99.8	527.6	80
11. East Macedonia	412 732	7 280	32	627	0.321
12. Thrace	404 182	11 177	27.9	825.2	11
13. Crete	601 131	8 335	42.33	320	4.1
14. Aegean Islands	508 807	9 103	37.19	80.2	1.24

Source: MoEPPW (2008)

4.1 The need for a 'Quick Appraisal'

In November 2007, the European Commission initiated legal action of 'Non-Conformity' against Greece (case C-264/07). In this action it is stated that "by failing to draw up by 22 December 2004 for each river basin district falling within its territory an analysis of its characteristics, a review of the impact of human activity on the status of surface waters and on groundwater and an economic analysis of water use, in accordance with the technical specifications set out in Annexes II and III, the Hellenic Republic has failed to fulfil its obligations under Article 5(1) of Directive 2000/60/EC establishing a framework for Community action in the field of water policy, while, by failing to submit summary reports of the analyses required under that article, it has also failed to fulfil its obligations under Article 15(2) of that directive." In response, the Ministry of Environment, Physical Planning and Public Works (MoEPPW) financed and supervised a series of studies required for the implementation of the WFD. A rapid-appraisal approach was required because of the severe information deficiencies and a time frame limit of 2 months defined by the Ministry.

The outcome was the Greek Report on the Implementation of Article 5 of the WFD (MoEPPW 2008). One of major challenges when producing this report was the significant lack of information. The preliminary analysis of water uses, pressures and impacts, under the first step of the implementation procedure, aiming to inform and guide the subsequent economic analysis was fragmentary. The only available source of information with regard to water uses in each River Basin District was a master plan study conducted by the Ministry of Environment that only contained general socio-economic information. Financial data from the drinking and irrigation water companies were not always available since their legal status does not oblige them to report their economic elements.

At the moment of the study, MoEPPW classified the conditions of water quality in each RB in three categories: good, moderate and bad. This categorization was done in terms of the concentrations of NO_3, P and NH_4 in each RBD. The concentration for each pollutant is characterized as Low, Moderate or High according to the levels of the pollutant factor. Table 4 presents the total number of the available measurements per pollutant and concentrations as well as the final condition of the RBD. West Macedonia and Thrace RBDs showed a bad quality condition under this classification.

Table 4: Overall condition of water quality

River Basin District	Concentration									Total Condition
	NO_3			P			NH_4			
	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	
1. West Peloponnese	2	0	1	2	0	0	0	0	0	Good
2. North Peloponnese	1	0	0	1	0	0	0	1	0	Good
3. East Peloponnese	1	1	0	2	0	0	1	0	0	Good
4. West Sterea Ellada	11	0	0	10	2	1	0	9	0	Good
5. Epirus	7	0	0	8	0	1	3	4	0	Good
6. Attica	1	0	0	2	0	0	1	0	0	Good
7. East Sterea Ellada	3	0	2	1	2	0	0	3	0	Moderate
8. Thessaly	3	1	0	2	2	0	0	4	0	Moderate
9. West Macedonia	12	1	1	10	3	10	0	11	5	Bad
10. Central Macedonia	7	0	0	2	1	7	0	7	0	Moderate
11. East Macedonia	7	0	0	3	3	3	0	7	0	Moderate
12. Thrace	8	9	1	0	5	12	0	13	4	Bad
13. Crete	4	0	0	4	0	0	4	0	0	Good
14. Aegean Islands	-	-	-	-	-	-	-	-	-	Good

Source: MoEPPW (2008)

Although Greece participated in the WFD intercalibration exercise (EC 2009), the implementation of the Article 4, which defines the environmental objectives per RBD was not completed at the time of the study and thus the environmental quality assessment was based on approximations from other existing studies. The agricultural census was not organized per RBD and the information with respect to cultivations and water demand were approximated. In the following section, we briefly discuss the methodologies used to calculate the Total Economic Cost of water resources in Greece for the Report on the Implementation of Article 5 of the WFD.

5. Methodologies used for calculation of Total Economic Cost of water resources

5.1 Financial Cost

The financial costs faced by water companies providing supply, sewerage and irrigation services include expenditures for cost of capital, operation and maintenance cost of the network, administrative costs, depreciation and other financial costs. The data were collected from the enterprises' annual published financial reports. However, financial data were not available for all the companies in all the RBDs. Therefore, the total financial cost was approximated assuming for the remaining enterprises the Greek mean financial cost per enterprise and aggregating over all operating enterprises. Table 5 presents the financial costs for domestic and agricultural water supply in each RBD.

Table 5: Financial cost per RBD

River Basin District	Financial Cost (€)	
	Domestic (€/hm^3)	Irrigation (€/ha)
1. West Peloponnesos	4 108 662	27.3
2. North Peloponnesos	4 612 819	14.6
3. East Peloponnesos	6 895 954	253
4. West Sterea Ellada	4 762 739	334.4
5. Epirus	5 684 518	319.2
6. Attica	833 711	13
7. East Sterea Ellada	3 378 763	10.07
8. Thessaly	6 850 916	63.9
9. West Macedonia	3 934 249	33.5
10. Central Mecedonia	2 091 853	53
11. East Macedonia	5 193 781	95.7
12. Thrace	2 746 149	28.6
13. Crete	5 258 926	33.8
14. Aegean Islands	9 530 520	10.3

Source: MoEPPW (2008)

5.2 Environmental cost

The cost associated with the reduction of water quality and the subsequent limitation of water resources' capacity to provide goods and services is the environmental cost. In an optimal scenario, original valuation studies are carried out in each water body of each RBD addressing the particular environmental problem in the area in order to obtain accurate welfare loss estimations. However, such studies are expensive and were not available. In this case a Benefits Transfer approach can be used in order to calculate the environmental cost. This approach allows values from existing studies to be transferred to policy sites of interest after correcting for certain parameters (Kirchhoff *et al.*, 1997; Desvousges *et al.*, 1992).

Therefore, a single value transfer was applied in the report and the environmental cost was estimated using existing valuation studies after proper adjustment. Welfare estimates in the considered studies are reported as willingness to pay for improvements in water quality (from bad or moderate to good) per individual and they were then aggregated over the population of each RBD. The zeros in the table indicate that the RBD has a good environmental status (recall table 4). The results of the environmental cost calculations are reported in Table 6. The largest environmental cost was found in northern Greece and specifically in Macedonia. Water quality in these regions is under severe stress since they concentrate most of the industrial activity in the country.

Table 6: Environmental Cost per RBD

River Basin District	Environmental Cost (€)
1. West Peloponnesos	0
2. North Peloponnesos	0
3. East Peloponnesos	0
4. West Sterea Ellada	0
5. Epirus	0
6. Attica	0
7. East Sterea Ellada	7 037 232
8. Thessaly	9 137 486
9. West Macedonia	14 535 598
10. Central Mecedonia	16 586 149
11. East Macedonia	5 025 462
12. Thrace	9 842 713
13. Crete	0
14. Aegean Islands	0

Source: MoEPPW (2008)

5.3 Resource cost

The resource cost results from scarcity arising due to overexploitation of water resources beyond their rate of replenishment. The resource cost was calculated for the water districts of Aegean Islands, East Sterea Ellada, Thessaly and East Peloponnesos, where water demand surpasses supply as indicated by their water balance. The resource cost is approximated by the cost of backstop technology to cover excess demand (Koundouri 2004). In several Aegean islands desalination plants are installed. Therefore, the price of this backstop technology was used to estimate the resource cost. The exploitation of other non-conventional water sources such as recycled water was the backstop technology relevant for East Peloponnesos and East Sterea Ellada.

Table 7: Resource cost per RBD

River Basin District	Resource Cost (€)
1. West Peloponnesos	0
2. North Peloponnesos	0
3. East Peloponnesos	3 510 184
4. West Sterea Ellada	0
5. Epirus	0
6. Attica	0
7. East Sterea Ellada	20 515 680
8. Thessaly	89 356 467
9. West Macedonia	0
10. Central Mecedonia	0
11. East Macedonia	0
12. Thrace	0
13. Crete	0
14. Aegean Islands	26 792 100

Source: *MoEPPW (2008)*

Finally, the excessive water demand in Thessaly is covered by the diversion of the river Acheloos. The resource cost was estimated by the product of the excess demand times the backstop technology cost per cubic meter of water which is €1.5m^3 for desalination plants and €0.5/m^3 for recycled water (WDD, 2005) and €0.818m^3 for the Acheloos diversion (personal communication MoEPPW). Table 7 reports the resource cost in each RBD. Thessaly has the largest resource cost since it is the most important agricultural region in Greece. The resource cost is also high in the Aegean Islands due to water shortages.

6. Assessment of cost –recovery level

6.1 Recovery from charges to users

An estimation of the cost-recovery level is possible once the total cost of water services is determined and the revenues of water companies are calculated. The cost recovery for irrigation companies was obtained multiplying the irrigation requirements times the mean irrigation water price per RBD.The cost recovery of water companies in the domestic sector comes from potable water pricing, sewerage connection and wastewater treatment pricing. The later, is calculated as a surcharge of 80% to the value of water consumption. Revenues from water consumption were obtained by multiplying the consumed cubic meters of water with the mean water price in each RBD whereas the sewerage expenses were inferred given the number of households in each RBD and the relevant fees set by the water companies.

Estimating the Cost- Recovery Level

The cost recovery level was calculated using the following equation:

$$Cost\,Recovery\,Level = \frac{Recovery}{Total\,Economic\,Cost}$$

Table 8 presents the results of the analysis of the cost recovery level. The mean cost recovery level per RBD in Greece was found 59.18%. In general, the revenues of water and sewerage services providers are not sufficient for the financial cost recovery and the cost recovery level of irrigation water is even lower.

Table 8: Cost Recovery Level in each RBD

	Cost Recovery Level (%)		
River Basin District	**Domestic**	**Irrigation**	**Total**
1. West Peloponnesos	62.21	11.44	50.54
2. North Peloponnesos	77.31	19.41	68.22
3. East Peloponnesos	37.89	15.66	34.18
4. West Sterea Ellada	61.29	14.28	46.19
5. Epirus	71	22.44	68.11
6. Attica	108.14	21.30	106.13
7. East Sterea Ellada	75.1	15.98	57.61
8. Thessaly	33.66	6.38	29.82
9. West Macedonia	53.55	41.05	51.71
10. Central Mecedonia	86.58	12.04	78.27
11. East Macedonia	79.39	27.38	70.74
12. Thrace	103.29	11.05	78.28
13. Crete	49.67	56.25	50.91
14. Aegean Islands	42.94	1.78	37.84

Source: *MoEPPW (2008)*

These estimates are broad estimates of the true recovery level. This approach is based on benefit transfers and reasonable assumptions, and allows for valuable conclusions to be reached regarding the limitations of the pricing policies that fail to reflect the true value of the resource and efficiently allocate it to competing demands. The methodology followed in the report can assist future efforts to fully comply with the EU-WFD reporting requirements.

7. Conclusions

In this chapter the evolution of the different water-related directives and regulations were presented in order to understand the requirements and challenges in implementation of the WFD in Greece. Then, the situation of the water sector in Greece was analysed in the context of a legal action of 'Non-Conformity' started by the European Commission against Greece (case C-264/07). A number of reasons explain the slow pace in the implementation of the WFD in Greece. For example, the hierarchical and centralized political and administrative structures in Greece have hindered the participation of the civil society in policy development for the management of water resources. There is little evidence of coherent interaction between the different levels of government in policy implementation, monitoring and enforcing. Overlapping responsibilities between competent authorities pose a serious constraint in efficient and sustainable water resources management. I

In consequence, the introduction of participatory arrangements required by the WFD has been extremely difficult. Therefore, difficulties can be expected in the implementation of the WFD in countries with weak institutional structure and limited financial resources. The Greek Report on the Implementation of Article 5 of the WFD provides a good example of the challenges and limitations encountered during the implementation of the Directive. A complete analysis of all pressures and impacts and a detailed assessment of the cost recovery in each river basin was extremely difficult due to the lack of information and the constrained time frame. Nevertheless, its results clearly highlight the need for reforms. The pricing policy in Greece requires changes in to achieve good ecological status in all water bodies and to ensure full recovery of the cost of water services.

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A Real Option framework towards analyzing coastal protection to sea level rise

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Abstract

Nowadays, it is widely accepted that climatic change intensifies the pressure on low-lying coastal areas bringing to the fore one of its most critical impacts, the global rise of mean sea level (SLR). Though SLR is not the only driver of coastal change, it is expected to alter radically the living conditions and prosperity of coastal communities in the decades to come, considering that there will be serious risks due to increasing flood frequency, inundation, coastal erosion, rising of water table, and saltwater intrusion. In order to minimize damages and losses, communities should make adaptation to SLR a priority. Nevertheless, coastal adaptation proves to be rather demanding due to the fact that SLR is a complex phenomenon, which is affected by both global conditions and local parameters. The latter add tremendously to the uncertainty involved in the assessments, creating significant ambiguity during the policy-making process. This paper aims to tackle with these challenges by presenting a modern management framework, namely Real Options, in the assessment of SLR adaptation strategies. The findings of the analysis indicate that Real Options, through recognizing the uncertainty and keeping all the options open till uncertainty is resolved, provides a detailed map for making adaptation decisions and enables to minimize investment risks by offering managerial flexibility and structure for scenario and strategy discussions.

Keywords: Climate change; sea level rise; adaptation measures; Real Options valuation.

JEL Codes: Q54; Q58.

1. Introduction

Coastal zone is an important natural resource for humanity due to the provision of valuable supportive (e.g. biochemical cycling, primary production, diversity, habitat, etc.), regulating (e.g. sediment retention, biological regulation, pollution control, etc.), provisioning (e.g. food, inedible resources, ornamental resources, etc.) and cultural services (e.g. recreation, aesthetic values, inspiration, etc.) (MEA, 2005; Garpe, 2008). Coastal zone is an important natural resource especially for Greece, considering that Greek coastline measures 16,400 km and about 33% of the Greek population inhabits in urban centers located at 1-2 km distance from the coast. In addition, about 80% of industrial activities, 90% of tourism and recreational activities, 35% of agriculture, fisheries and aquaculture, as well as an important part of infrastructures (ports, airports, roads, electricity and telecommunications network, etc.) are located in the coastal zone (Kontogianni et al., 2011a). Furthermore, over 6,000 different flora species, 670 vertebrate species and 436 avifauna species are found in Greece's coastline (ibid.). A major problem of the Greek coastal zone is the high rate of coastline erosion. Over 20% of the total coastline is under threat (EUROSION, 2004), owing primarily to the strong winds and the storm surges in the Aegean Sea, as well as anthropogenic interventions. The problem is expected to grow in the future due to: (a) the predicted sea level rise (SLR); (b) the aggravation of extreme events and; (c) the further reduction of the river sediment flows (IPCC, 2007; Velegrakis et al., 2009).

Focusing on the effects of SLR, there will be serious risks to coastal communities and ecosystems due to increasing flood frequency, inundation, coastal erosion, rising of water table, and saltwater intrusion (Nicholls, 2003; Kulpraneet, 2012) and, consequently, major socio-economic and environmental implications. In order to reduce the risk of SLR damages, coastal communities should design and implement appropriate adaptation strategies. However, policy formulation for SLR risks management becomes a complex issue due to the uncertainty involved regarding the actual effects of climate to SLR, as well as the anthropogenic interventions taking place in coastal land (Kontogianni et al., 2011b). For instance, according to IPCC (2007), global warming could increase sea level from 0.18 to 0.59 m by the end of the 21st century, while Dasgupta et al. (2007) mention that an unexpectedly rapid breakup of the Greenland and West Antarctic ice sheets might produce a 5 m SLR.

Considering the above remarks, this paper wishes to contribute to existing literature by presenting a modern management framework, namely Real Options, in estimating SLR costs and adaptation benefits for policy sxenarios. For this purpose, the analysis uses a specific case study and it provides, first, a probabilistic estimation of SLR costs and benefits to highlight the range of probable outcomes and, then, it implements the use of Real Options valuation in designing optimum SLR adaptation strategies.

2. Background information

Eresos beach is located along the SW coast of the Island of Lesvos, Greece. Near shore bathymetry is shallow, but depths increase rapidly offshore, reaching 100 m in less than 1.4 km from the coastline (Chatzipavlis et al., 2012). Closure depth is estimated to be at ~5 m and at a distance of ~250 m from the coastline (Adamakis, 2005). The beach under investigation is exposed to SE, S, SW and W winds (Pasakalidou, 2007). Recently, a change in the frequency of the SW, S and SE has been noticed, which may contribute to increased coastal erosion in the eastern section of the beach (Andreadis, 2005; Pasakalidou, 2007).

Along the eastern part of the beach, a seawall and a small fishing harbor have been constructed, which may intensify beach erosion phenomena (Karambas, 2010). During December 2010 and early January 2012, intensive southerly winds generated storm surges/waves that destroyed an existing seawall and inundated beachfront properties (Chatzipavlis et al., 2012). Eresos beach, particularly its central and eastern part is under erosion (Adamakis, 2005; Andreadis, 2005). Doukakis (2008) quantified the impacts from the SLR in the coastal area of Eresos. The length of the shoreline examined was approximately 2.5 km. The estimation of the impacts was performed utilizing the Bruun erosion model, which is a one-dimensional model for the prediction of the future retreat of sandy shorelines. Moreover, the historical SLR of the adjacent coasts of Chios and Turkey were taken into consideration. Two scenarios were assessed assuming closure depth equal to 5 m and 10 m and SLR equal to 30 cm until 2050. The obtained results showed that the coastal land loss due to erosion and SLR will be equal to 3.6 ha for the first scenario (closure depth = 5 m and SLR = 30 cm) and equal to 2.8 ha for the second scenario (closure depth = 10 m and SLR = 30 cm), respectively. The results confirmed the fact that the climate change will affect adversely the housing and commercial activities in the coastal area of Eresos and the adoption of adaptation measures for the confrontation of the impacts is imperative.

3. Methodological framework

3.1. SLR adaptation and Real Options

The selection of appropriate adaptation measures to cope with SLR issues is based on the net benefits of the proposed actions, which are summed up over the life of the adaptation project and discounted back to present values, according to Eq. 1 next:

$$\mathrm{B} = \sum_{i=1}^{T} \frac{AvD_i - AdC_i - \mathrm{Re}\,C_i}{(1+r)^i} \qquad (1)$$

where B are the net benefits in present value terms, T is the period over which the action is analyzed, AvD_i is the avoided damage in year i, AdC_i is the total adaptation cost (e.g. construction, operation and maintenance of SLR measures) in year i, ReC_i is the cost of the residual damages in year i, and r is the discount rate.

To this end, decision-makers use either deterministic estimation techniques (i.e. they adopt ‘best-guess’ values regarding the gradual evaluation of SLR over time, the necessary adaptation cost, the avoided damages, etc.) or probabilistic approaches, such as Monte Carlo simulations, in order to tackle with the uncertainty involved in the estimates. The latter approach assumes that the critical parameters that affect the problem can be described by means of probability distributions and the problem is solved in a stochastic context. In addition, probabilistic analysis provides a range of likely outcomes and, thus, is considered to be more comprehensive than deterministic analysis. Nevertheless, both approaches share a common drawback: they establish a “now-or-never” decision-making framework, in which policy- and decision-makers face the dilemma of whether to invest *now* in order to adapt to potential SLR effects or to take the *risk of delaying* the adaptation measures until uncertainty clears.

An investment decision, especially for ‘hard’ engineering structures that are commonly used to protect coastal areas from erosion phenomena, is rarely a “now-or-never” proposition. In most instances, adaptation strategies come in the form of sequential steps with various decision points and they can be postponed, altered or even abandoned (Nembhard & Aktan, 2009). Provided that flexibility is a requirement towards developing coastal adaptation strategies, which is not satisfied by deterministic or probabilistic analyses, a new framework has emerged in the field of climate change adaptation in the past few years, namely Real Options Valuation (ROV). Some organizations have already proposed ROV as an appropriate tool for assessing climate change adaptation strategies (e.g. H.M. Treasury, 2009; World Bank, 2009 & 2011). So far, however, the use of ROV to appraise adaptation actions is limited and there exist only a few examples of ROV applications in the protection of coastal areas in Greece (Kontogianni et al., 2013), in the State of Campeche, Mexico (Scandizzo, 2012) in a riverine delta, Dhaka, Bangladesh, on an ocean coast, Dar-es-Salaam, Tanzania (Linquiti and Vonortas, 2012), in flood risk management strategies in the Thamesmead area of the Thames Estuary, UK (Woodward et al., 2011), and in the comparison of housing alternatives in Mekong Delta of Viet Nam (Dobes, 2010).

3.2. ROV fundamentals

ROV has its roots in financial options analysis, in particular the theories that were developed by Black and Scholes (1973) and Merton (1973). In general, a real option is "a right, not an obligation", to take an action to future developments, which may involve abandoning or expanding a project, or deferring the decision until the uncertainty becomes resolved (Kodukula & Papudesu 2006; de Neufville et al., 2009). In order to acquire the option, an option price or premium has to be paid, similar to financial options. At the expiration date the option owner has the right to buy or sell the underlying asset at the exercise or strike price (Mun 2006). The solution of RO models is based on multiple techniques, e.g. partial differential equations, closed form equations like the Black-Scholes model, Monte Carlo path-dependent simulations and binomial or multinomial lattices, which are applied in the present study.

ROV distinguishes from DCF and other conventional tools in that it incorporates a learning model and offers a strategic map that outlines the contingent decisions in the light of gradual resolution of uncertainty (Kodukula & Papudesu 2006; Nembhard & Aktan, 2009). For this reason, ROV is valuable and worth applying when there exists high uncertainty and potential for managerial flexibility. ROV is most valuable for longer-term projects, due to the fact that: (a) the future is most uncertain for longer-term projects and (b) the system managers have significant flexibility to modify the course of a project easily, i.e. to influence the size and timing of the investment (de Neufville et al., 2009). Nevertheless, ROV should be considered as a supplement rather than a substitute for traditional valuation tools (Kodukula & Papudesu 2006).

3.3. Analytical framework and assumptions

3.3.1. Analytical framework

In order to illustrate the application of ROV in SLR adaptation strategies in the case studied, it is assumed that the policy-maker has acquired the option to defer investing in coastal defenses until uncertainty becomes resolved through the passage of time. This means that the adaptation measures will be constructed only if SLR conditions indicate their necessity; otherwise, they will be abandoned. To this direction, a binomial lattice approach is adopted, assuming that the option has a fixed date that can be exercised (i.e. a European option). The binomial lattice is a discrete simulation of the uncertainty over the life of the 'option'. The ROV model involves two lattices, namely the 'underlying asset' and the 'option' value lattices. The basic inputs are, as follows:

- the present value of the underlying asset at year 0 (S_0), i.e. the present value of adaptation benefits
- the present value of the implementation cost of the option (X), the present value of the investing cost of the adaptation measures
- the time to expiration (T, in years)
- the risk-free rate of return (rf, in percent)
- the stepping time, i.e. time scale between steps (δt in years).
- the volatility of the underlying cash flow returns (σ, in percent)

The estimation of the volatility factor is a challenging issue in ROV analysis and there are several methods for estimating it. In this application, the management assumption approach was employed using the results of the Monte Carlo simulation for the cost-benefit analysis of each measure studied, using the following Eq. 2 (Mun, 2006):

$$\sigma = \frac{NPV \ \ percentile\,value - Mean\ NPV}{Inverse\,of\ \ the\ percentile \times Mean\ NPV} \tag{2}$$

It is noted that the volatility factor used should be consistent with the time step used in the corresponding equations (Kodukula & Papudesu, 2006).

a. The underlying asset value binomial lattice

Supposing that the present (i.e. initial) value of the expected adaptation benefits at year 0 is S_0, this value either increases or decreases at each predefined time interval. The underlying asset value binomial lattice represents these different possible paths, which are created by multiplying S_0 with the up (u) and down (d) factors. The asset-pricing lattice is presented in Table 1. Moving one column to the right in a row means a value increase with the rate of u, and moving one column to the right and one row down together means a value decrease with the rate of d.

Table 1: Binomial lattice of the underlying asset value

Today	Time-step 1	Time-step 2	Time-step 3	Time-step 4
S_0	S_0u	S_0u^2	S_0u^3	S_0u^4
	S_0d	S_0ud	S_0u^2d	S_0u^3d
		S_0d^2	S_0ud^2	$S_0u^2d^2$
			S_0d^3	S_0ud^3
				S_0d^4

The up (u) and down (d) factors are calculated, as follows (Eq. 3):

$$u = e^{\sigma\sqrt{\delta t}}, \quad d = e^{-\sigma\sqrt{\delta t}} = 1/u \tag{3}$$

b. The option valuation binomial lattice

The calculation of the option valuation lattice requires a two step procedure, which is called backward induction. The calculation starts with the terminal nodes. Given that the decision-maker wishes to maximize the expected benefits, if the execution of the option (i.e. S-X) yields benefit, then the value becomes equal to that profit. If the cost exceeds the benefit of execution, then the value becomes equal to 0. The second step involves the calculation of the intermediate nodes, using the risk-neutral probability measure (p), from the following Eq. 4:

$$\text{node value} = [(p)u + (1-p)d]e^{(-rf \times \delta t)} \tag{4}$$

where the risk-neutral probability measure (p) is (Eq. 5):

$$p = \frac{e^{(rf \times \delta t)} - d}{u - d} \tag{5}$$

The intermediate values become equal to the discounted weighted average of future option values. For instance, the node value S_0u^2 is estimated by the node values of S_0u^3 and S_0u^2d, according to the following Eq. 6:

$$S_0u^2 = [(p)S_0u^3 + (1-p)S_0u^2d]e^{(-rf \times \delta t)} \tag{6}$$

The decision whether to keep the option open or exercise the option is defined by the maximum of the two outcomes, namely the execution of the option (i.e. S-X) and the value of the intermediate node (i.e. the discounted weighted average of future option values, described above).

3.3.2. Basic assumptions

To illustrate the use of ROV in coastal adaptation decision-making process, two different adaptation strategies are examined for the Eresos beach, namely the implementation of bulkheads and the combination of revetments and geotextiles. More specifically, the total investment *now* in adaptation options is analyzed, estimating the present value of net benefits of each adaptation measure by means of stochastic simulations. Then, by means of ROV, the proposed measures are evaluated in any year during the examined period. Nevertheless, for conciseness reasons, it is assumed that the decision to intervene can be taken once every 10 years in five time-steps, i.e. now (for simplifying the calculations 'now' refers to year 2010), 2020, 2030, 2040 and 2050.

Several published studies present overall assessments of adaptation costs (e.g. UNFCCC, 2010; Agrawala et al., 2010). As regards the adaptation measures examined in this study, Kourogeni and Karabas (2010) estimated the construction cost of a coastal adaptation project in Greece combining revetments and geotextiles (325 €/m - 425 €/m) and the implementation of bulkheads (425 €/m - 635 €/m). The avoided damages were estimated on the basis of the land saved, using the unit values described in the following paragraph, while the residual costs were estimated assuming an efficiency of the proposed actions of about 80% (i.e. 20% of the land may be inundated despite the construction of coastal defenses). As regards the estimation of the present value of cost and benefits, a 3% discounting factor was used.

4. Results

4.1. Probabilistic analysis

The severity of SLR impacts on coastal areas precludes uncertainties about the intensity of SLR, the relationship between the tectonic elevation and the eustatic SLR, which for many areas of the Greek territory is quite significant, and the sedimentation of clastic materials in coastal areas (Kontogianni et al. 2011b). In addition, there are also uncertainties in the estimates associated with the unit values used in order to calculate the economic losses from land loss and ecosystem degradation. According to these remarks, the estimations of SLR costs are mainly affected by: (a) the total inundated land area, (b) the choice of the appropriate unit value per land use and, (c) the cost and the efficiency of the adaptation measures.

To analyze the influence of uncertainty on SLR damages in Eresos beach, a Monte Carlo simulation analysis was carried out. To this end, the following assumptions were adopted:

- The inundated land area follows a uniform distribution between 2.8 and 3.6 ha based on Doukakis (2008) research.
- The expected land damaged refers solely on housing and touristic areas. Due to wide variation of property values, a triangular distribution was used with a representative price of 1,200 €/m^2, a minimum value of 700 €/m^2, and a maximum value of 1,500 €/m^2.
- The cost of engineering structures follows a triangular distribution. More specifically, the cost of revetments and geotextiles ranges from 325 €/m to 425 €/m, with mean value 375 €/m and the cost of bulkheads lies between 425 €/m and 635 €/m, with most plausible value 530 €/m.
- The efficiency of the proposed adaptation actions follows a triangular distribution with mean value 80% and minimum and maximum values 70% and 100%, respectively.

Table 2 presents the results of Monte Carlo simulation for discounting factor 3%.

Table 2: Probabilistic results for net adaptation benefits – PV in € (r=3%)

Variable	Revetments & Geotextiles	Bulkhead
Mean	6,504,000	6,157,000
st. dev.	1,853,000	1,920,000
Minimum	2,080,000	1,969,000
Maximum	12,032,000	12,866,000

According to the results, the adaptation measures are justified in both cases, although it is more preferable to use revetments and geotextiles than bulkhead. Nevertheless, it is a "take-it-or-leave-it" decision with limited or not at all flexibility.

4.2. ROV analysis

The inputs of the ROV models for the adaptation measures examined were estimated using equations (2)-(6) and the results of the Monte Carlo simulations and are presented in the following Table 3.

Table 3: ROV models inputs

Variable	Revetments & Geotextiles	Bulkhead
X	937,500	1,325,000
S_0	6,180,000	6,180,000
δt	10 years	10 years
T	40 years	40 years
rf	1.8%	1.8%
σ	0.156	0.171
u	1.636	1.719
d	0.611	0.582
p	0.572	0.541

For conciseness reasons, the step-by-step analysis is performed only for the case of bulkhead. To this end, Fig. 1 and 2 show the underlying asset value and the option value binomial lattices.

Figure 1: Asset valuation binomial lattice for the bulkhead

Today (2010)	2020	2030	2040	2050
6,180,000	10,624,459	18,265,230	31,401,000	53,983,596
	3,594,762	6,180,000	10,624,459	18,265,230
		2,090,989	3,594,762	6,180,000
			1,216,280	2,090,989
				707,482

The calculation of the option valuation lattice (Fig. 2) starts with the terminal nodes. For instance, the value in node S_0u^4 is 52.66 M€ (=53.98-1.33 M€). The value in node S_0d^4 is 0, since the benefit in node is S_0d^4 is 0.71 M€ but the cost of execution 1.33 M€, leaving a loss of 0.62 M€. Continuing with the calculation of the intermediate nodes, in node S_0ud^2 the value of executing the option is 2.27 M€ (=3.60-1.33 M€). Nevertheless, keeping the option open, the value becomes equal to the discounted weighted average of future option values, i.e. 2.49 M€. Thus, the decision would be to keep the option open and the value would be equal to the maximum of the two outcomes. The same procedure is employed for the rest of the intermediate nodes back to the starting point to obtain the value of 5.55 M€, which represents the Expanded PV of the benefits or the so-called Total Strategic Value of the project.

Bearing in mind the option valuation lattice, the decision-maker will choose the strategy depicted in Fig. 3 that maximizes the benefits of the adaptation program.

Figure 2: Option valuation binomial lattice for the bulkhead

Today (2010)	2020	2030	2040	2050
5,548,379	9,852,317	17,340,809	30,294,267	52,658,596
	2,857,388	5,255,579	9,517,726	16,940,230
		1,257,281	2,488,029	4,855,000
			346,225	765,989
				0

Figure 3. Decision lattice for the bulkhead

Today (2010)	2020	2030	2040	2050
continue	continue	continue	continue	end
	continue	continue	continue	end
		continue	continue	end
			continue	end
				abandon

According to the discounted values, the ‘static’ present value of benefits for the bulkhead is 4.86 M€ (6.18 M€ minus the investment cost). Therefore, ROV analysis provides an additional value of €690,000, which may be considered as the maximum price the buyer would be willing to pay to obtain this option. Using the same process for the case of revetments and geotextiles, the additional value provided by ROV in comparison to ‘traditional’ tools is estimated at €480,000. The additional value could be utilized in deciding whether resources should be invested in science research to help policy- and decision-makers, governments and international organizations clear SLR uncertainty (i.e. investments dedicated to ‘active learning’) or not to invest at all and wait for uncertainty resolved through the passage of time (i.e. ‘passive learning’) (Kontogianni et al., 2013).

5. Conclusions

The present paper presents a promising approach that enables decision-makers to incorporate uncertainty and flexibility dimensions in SLR adaptation strategies. To this end, the Eresos beach is used as case study building on the results of a previous research of Doukakis (2008). The findings show that ROV may provide decision-makers with the flexibility to ‘adjust’ coastal protection measures, in terms of deferral, acceleration or abandonment of engineering structures, to future conditions. In this way, governments and local authorities would commit the resources necessary to address SLR impacts without jeopardizing economic growth. However, the use of ROV in the field of climate change-induced SLR requires further research in order to get a deeper understanding of the applicability of existing RO models to ‘hard’ engineering measures. Furthermore, the influence of socio-demographical, behavioural and attitudinal factors, such as the culture and training of engineers and of other scientists involved in climate change policy networks, should be examined, so as to eliminate existing barriers.

Acknowledgments

This research has been co ‐ financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) ‐ Research Funding Program: THALES. Investing in knowledge society through the European Social Fund.

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The value of scientific information on climate change: A choice experiment on Rokua esker, Finland

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Abstract

This article presents an application of the choice experiment method in order to provide estimates of economic values generated by water quantity improvements in the environment. More importantly, this is the first choice experiment study valuing scientific information and in particular scientific information on climate change. The case study of interest is Rokua in Northern Finland, a groundwater dependent ecosystem very sensitive to climate change and natural variability. The study deals with the uncertainty about the actual dynamics of the system and the effect of future climate change by exploring whether the public values sustained provision of resources for scientific research to better understand long-term environmental changes in Rokua. Data are analysed using a nested multinomial logit and an error component model. Evidence from this study suggests that individuals are willing to pay in order to assure scientific research so as to better understand long-term environmental changes. As a result, policy should consider investing in and supporting related research. Other aspects of water management policy valued by the public are water quantity, recreation, and total land income.

Keywords: Choice experiment method; nested logit model; error component model; willingness to pay; improved scientific information; water management practices.

1. Introduction

Water provides one of the most important life-support functions, ensuring food security through agricultural production and enabling the existence of all ecosystems. Yet groundwater resources are facing increasing quantitative pressure from land use and consumption pressures and there is evidence of dramatic changes in aquifer resources in Europe (Klove et al., 2011). The complexity of the relationships among groundwater and surface water and the failure to understand the consequences of land use and water management result to an information breakdown (WWF, 2004) which is the root cause of groundwater dependent ecosystems degradations. Climate change introduces an additional element of uncertainty in water resource management in which the future effect of climate change is dependent on trends in both climatic and non climatic factors (IPCC, 2007). All regions of the world show an overall net negative impact of climate change and freshwater resources and ecosystems and many areas are likely to face a reduction in the value of the services provided by water resources (IPCC, 2007). Adaptation of measures and application of appropriate management practices have an important role in determining the impact of climate change on water resources and on ecosystems.

A choice experiment is employed in Rokua esker, Finland to show how preferences of people are being shaped with regards to different sustainable water management scenarios in a groundwater dependent ecosystem, very sensitive to climate change and natural variability. The purpose of the choice experiment is to estimate benefits generated by water management practices and improved scientific information that would reduce the risk of a future deterioration and would allow achieving/sustaining the targets of the relevant European environmental legislation, Water Framework Directive (WFD) (2000/60/EC) and Groundwater Directive (2006/118/EC). Benefits from achieving good water status consist among others from recreational values, scientific value on climate change, and socio-economic values like potential tourism opportunities. Currently choice experiment offers the most promising approach to value non-marketed environmental goods.

It has been widely applied for the valuation of wetlands' management, e.g. studies of Carlsson Frykblom and Liljenstolpe (2003), Birol, Karousakis and Koundouri (2006), Morrison, Bennett and Blamey (1998), Othman, Bennett and Blamey (2004), Birol and Cox (2007), for the valuation of surface water quality and quantity e.g. Hanley, Wright and Alvarez-Farizo (2006) and for groundwater quality and quantity, e.g. Hasler, Lundhede and Martinsen (2005). Also, a contingent valuation question and a split-sample survey format are additionally employed to investigate risk behaviour of the respondents under uncertain future environmental losses.

The rest of the study unfolds as follow. Section 2 presents the case study of Rokua. Next Section 3 provides a short description of market failure leading to unsustainable water resources and presents the concept of total economic value and the role of economic valuation techniques. It follows Section 4 which explains the methodology. Choice experiment application, contingent valuation and survey design is presented in section 5. Descriptive statistics and results of the pre-testing survey are presented in Section 6 and Section 7 respectively. Section 8 discusses the study and concludes with the future tasks to be completed.

2. Rokua Case Study

The case study is Rokua esker located in Northern Finland and it is part of a chain of esker ridges. Small "kettle" lakes are situated within the esker area. Wetlands found there, are unique biological resources and highly important for sustaining biodiversity. Rokua is a recognized natural reserve; some lakes are already protected by Natura 2000 and the area is a new introduced member of the UNESCO GeoPark Network. Rokua is a very popular recreation area. Groundwater area is surrounded by peat land drainage.

Rokua is a dependent groundwater ecosystem. As such, the water level of most of the lakes' in Rokua is a function of the level of the groundwater table of the esker, the latter is naturally recharged. However, during the last few decades, it has been observed a significant reduction in the water level of small lakes. Scientists after monitoring groundwater quantity observed that groundwater level tended to decline while precipitation-evaporation ratio was increasing.

For this decline in water quantity many reasons have been discussed such as climate change or the land use and drainage. Forest drainage of the surrounding peatlands seems to disturb groundwater dynamics and thereby water level of lakes. Lodging activities and peat harvesting appear to influence water quantity. Drainage, in addition, affects negatively spring ecosystems which are considered key biotopes of forest conservation in Finland. However there is yet a degree of uncertainty as scientific knowledge is lacking on this complex ecosystem. The impacts of drainage and also the natural variability or impact of climate change on groundwater dynamics are not very clear yet. Even though more research is needed in order to better understand the extent and the nature of the problem, scientific observations give sufficient evidence that a policy to mitigate a possible future environmental deterioration is needed.

3. Water Resources as an economic good

The aim of this section is to provide a short introduction on the underlying economic theory with respect to environmental goods. Also explains the nature and the components of values individuals may derive from water resources and ecosystem services and explains the need for economic valuations techniques in designing sustainable management practices and policy instruments.

3.1 Market Failure and Total Economic Value

Water resources and services as an economic good share the public good property of non excludability in consumption; i.e. provision to one individual does not prevent others from using it. Public good feature of water leads to market failure mainly associated with missing property rights and presence of externalities (Karousakis and Koundouri, 2006).

An externality arises when social or economic activities of one group of persons have an impact on another and when that impact is not fully informed or compensated for by the first group, Externe (2005). Water resources affect the well-being of individuals with various ways and provide a variety of services. Many of the ecosystems functions that water resources sustain, e.g. among others recreation and aesthetic benefits, biodiversity benefits, research benefits, existence benefits, do not have a market price and as such are not recognized as having an economic value by the decision makers (Bateman et al., 2003, Perman et al. 2003). Though a loss, or even a potential future loss, of environmental services due to unregulated use of water in a groundwater dependent ecosystem is a cost to local society, users have no incentive to account for these damages when making decisions. This means that private optimum divergences from social optimal allocation. From a microeconomic view, in such conditions prices are not the correct signals because they do not capture the total economic value. The optimal price of water should capture the marginal private cost, the marginal environmental costs and also the potential future costs associated with the extraction of water due to uncertainty in climate change and natural variability (Karousakis and Koundouri, 2006). Environmental costs and resources costs of goods are ignored resulting to a lower private cost and thereby excessive production or consumption of the good that generates the externality. Water is not allocated efficiently amongst the resource users implying that society would benefit more from a different allocation of water among sectors. Economic instruments and sustainable management techniques should be employed in order to internalize external effect into the decision process. In order to do so first it is required to measure the total value of damages, or benefits from the avoidance of damages, to society in monetary terms and then explore how these external elements can be charged to different stakeholders (Pearce and Ozdemiroglu, 2002).

The concept of total economic value is an essential theoretical framework for the implementation of economic valuation exercises. Total Economic Value (TEV) of an environmental resource is defined as the whole class of values that have a basis in human preferences (Karousakis & Koundouri, 2006).

Individuals' preferences reflect the utility derived from the consumption of any good. Thus have a determinant role on assigning total economic values. Individuals are expected to derive utility from the consumption of a good or service. This is called actual use value and is composed of *direct use value* (i.e. commercial and recreational) and *indirect use value* (i.e. amenity value). People may also derive utility from retaining an option to a good or service. Option value reflects the potential future direct and indirect use values. Non-use values reflect individuals' preferences that may exist for an environmental good even when no actual or future use is expected to be made. Examples of non-use values are the *existence values* derived from the demand to preserve the existence of resources unrelated to any use and the *bequest* and *altruistic* values. The latter involve individuals' willingness to pay for an environmental resource for others, i.e. children or future generations (Pearce, 1993; Karousakis and Koundouri, 2006).

Water resources in Rokua provide a diverse array of goods and services which can be translated to values that directly or indirectly local society and visitors undertake, see Table 1.

Table 1: Total Economic Value Components of Water Resources in Rokua

Direct Use Values	Forestry
	Energy resources (peatland)
	Recreation
	Domestic water supply
	Irrigation for agriculture
Indirect Use Values	*Nutrient retention*
	Pollution abatement
	External eco-system support
	Micro-climatic stabilisation
	Reduced global warming
	Soil erosion control
Option Values	Potential future uses of direct and indirect uses
	Future value of information on climate change
Non-use Values	*Biodiversity*
	Cultural heritage
	Bequest, existence and altruistic values

(Adopted and modified from Barbier et al., 1997)

In Rokua there have been identified four different stakeholders groups, namely local residents, 2nd house owners, forestry – peatland industry and recreation, who are hypothesized to derive economic benefits, mainly use values and options values, from the wetlands' ecosystem goods and services. The driving forces of water demand in Rokua are strongly linked with local economic policies, mostly related to land use issues, and additional forces of water shortages are due to natural variability and climate change.

3.2 Economic Valuation Techniques and their role in policy design

Economists have developed various approaches in order to be able to quantify values which contribute to social welfare associated with environmental goods. Economic valuation refers to the assignment of monetary values, which have a particular and precise meaning, to non-marketed assets, goods and services (Pearce and Ozdemiroglu, 2002). The strongest argument for assigning economic values is the use of valuation results in policy design. Theory underlies that if external effects are omitted from appraisal there is high risk that non-marketed goods will be under-supplied while non-marketed bad will be oversupplied. As it was mentioned in the beginning of this section since the market mechanism is not able to capture the total value of environmental goods, public intervention is needed in order externalities be internalized into the decision process. Though there are many issues arising on how to introduce monetary valuation into public decision making, monetary benefit estimates can serve four basic purposes (Bonnieux & Rainelli, 1999 in Bateman & Willis):

1. Contribute to public debate and awareness concerning specific (environmental) problems. Money serves as a readily understandable indicator of environmental damage or potential benefits
2. Influence particular decisions by using a cost benefit analysis or comparison of costs and benefits in another way
3. Identify the optimal alternative among competing options
4. Support and justify decisions (ex ante ad ex post) taken by government agencies.

It is important water management practices to be made compatible with social objectives, i.e. efficiency, equity and sustainability considerations (Karousakis and Koundouri, 2006). Preferences elicitation for different socio-economic groups and knowledge of the marginal valuation each group attaches to environmental improvements through valuation studies allows for equity considerations to be taken into account in the formulation of policy responses (Remoundou & Koundouri, 2009). Economic estimates give also information regarding the best use of available resources i.e. the option that has the lowest opportunity cost or the lowest valued to be sacrificed. Monetary value assessment allows the ranking of alternative policy options allowing the implementation of cost-benefit analysis for policy guidance.

A variety of techniques are available, the main methodological approaches of economic valuation can be broadly classified into revealed and stated preferences techniques (among others Bateman et al., 2002; Bateman et al., 2003). Revealed Preferences techniques rely on market observations to capture the value of an environmental good that it is not itself traded in any market but is in a way connected with other marketed goods. From people's behavior in markets it is possible to isolate values of changes in environmental goods. In stated preferences techniques a hypothetical market for the good is being constructed through the use of questionnaires. In this market individuals have the opportunity to pay for an environmental improvement that will increase their utility. All available techniques differ in the data demands, assumptions and in the values that are able to capture. Each technique has its own advantages and limitations. The selection of the appropriate technique should be case driven and be dependent of the policy examined. In Rokua case study, evaluation problem occurs in a framework for which no value measures can be derived from observing individual choices through markets. This is mainly due to public good aspect of groundwater quantity, to the nature of values we are interested to capture and to the fact that the policy change examined is potential rather than actual. Thus employment of stated preferences techniques, namely choice experiment and contingent valuation, are by far the most appropriate method to assign values to the benefits generated from the revision of water management in Rokua esker.

4. Methodology

Choice Experiment (CE) method is a survey-based technique which can estimate the total economic value of an environmental good. The foundations of Choice Experiments lay back in Lancaster's Theory of Value. As Lancaster (1966) mentioned, satisfaction each individual derives from a commodity depends on the vector of characteristics and attributes this commodity provides rather than the commodity itself. Within that framework, water resources can be seen as a multi-attribute environmental commodity and choice experiment can be employed to measure total economic value and to distinguish the value of each component as well as the trade off between these components. The selected attributes in each case are ought to be part of people's preference for the environmental change being considered and can be impacted by a management policy option (Bateman et al, 2002). Different combinations of the levels of attributes are used to describe different alternatives of the policy examined. These alternatives are putted together in choice sets using experimental design theory (see Louviere et al. 2000).

In this method, individuals instead of being asked directly to state their valuation in monetary terms, estimates of values are inferred from the hypothetical choices or trade-offs that make among many alternatives. Each respondent is presented with a series of hypothetical alternatives of an environmental stock, flow or service with varying levels of its price and asked to choose the most preferred option in each set of alternatives (Karousakis and Koundouri, 2006). A status quo is included in each choice set to be able to produce welfare estimates that are consistent with demand theory (Bateman et al. 2003).

If one of the attributes is a monetary one, i.e. cost made by the household for the implementation of the proposed policy option, then trade-offs between variables can be expressed in willingness to pay terms. Thus an implicit price is attached on each attribute. Compensating surplus measures can also be estimated by willingness to pay for a movement from the status to an alternative (Perman, 2003).

Contingent Valuation (CV) is another very popular survey based method technique**.** In CV a hypothetical market is being created and respondents are asked directly to express their willingness to pay for existing or potential environmental conditions not registered on any market, i.e. contingent on some hypothetical change in the future state of the world, through the use of a questionnaire (Mitchell & Carson, 1989). Alternatively, in case of an environmental deterioration this can be expressed as the minimum monetary compensation they would accept to tolerate a reduction in environmental quality.

CV method includes a description of the environmental change in question, of the contingent market and a selection of a payment vehicle. WTP bids can be elicited through a variety of methods including an open-ended format, a bidding game, a payment card or a single or double-bounded dichotomous choice mechanism. Mean and median WTP can be estimated and then the average bid can be aggregated to a population total value (Karousakis and Koundouri, 2006). The literature on the contingent valuation method's advantages and disadvantages is large. There are many problems associated with CV method that may bias the estimates for example interviewing bias, non-response bias, strategic bias, embedding effects, yea-saying bias, hypothetical bias, information bias (Bateman et al. 2002). NOOA Panel set the guidelines for the implementation of reliable contingent valuation exercises (Arrow et, 1993). Choice experiments have many advantages over other valuation methods. As Boxal et al. (1996) argued their experimental nature which enables the representation of different states of the environment using attributes and levels of specific choice situations make this technique superior. Also choice experiment eliminate or minimise several of the problems attached to contingent valuation (Bateman et al, 2002).Given that stated preferences techniques rely on hypothetical choices, choice experiment and contingent valuation face similar problems with regards to the survey design and administration.

4.1 Econometric Specification

The econometric basis of a choice experiment lay in Random Utility Theory (McFadden, 1974). Random utility theory assumes that overall utility is the sum of a deterministic component and a random component. Utility of a choice is depended systematically on the attributes of the alternatives but also on factors unobservable which are accounted for in a stochastic error term (Green, 2008). Stochastic elements not only represent the unobserved individual heterogeneity but also imply that predictions can not be made with certainty.

To illustrate the choice experiment of this study assume a local's resident choice for a water management programme, under the assumption that utility depends on choices made from a choice set which includes all the possible water management alternatives j=1,…J. Each alternative in a choice set, under the random utility theory, has an associated utility level for each individual i that is represented by:

$$U_{i,j} = V(X_{i,j}, Z_i) + e_i = X'_{i,j}\beta + Z'_i\gamma + e_i$$

Where (X) is the vector of attributes of the management scenario under evaluation and (Z) is the vector of the socio-economic characteristics of the respondent. The assumption behind the analysis is that given a finite set of alternative management scenarios j characterized by distinct environmental attributes (X_j), an individual i will choose a scenario on the basis of selecting the one among the available which confers the highest utility (Perman, 2003, pp. 438). The observed choice between the alternatives reveals which one provides the greater utility and not the actual level of utility (Green, 2008). A contingent valuation exercise can be seen as a restricted form of the above where individuals face one single alternative to the status quo, i.e. j=1.

The specification of the econometric model depends on the specification of the utility function and of the probability distribution of the error term (Alpiraz et al., 2001). Assuming that the relationship between utility and attributes is linear in parameters and that the random components are identically and independently distributed with a Gumbel (type 1 extreme value) distribution, the probability to choose any particular programme alternative j can be estimated with a multinomial logit model (Greene, 2008 pp. 843).

The main limitation of MNL is the restrictive assumption of independence of irrelevant alternatives. IIA implies that the ratio of choices between two alternatives in a choice set is unaffected by changes in that choice set (Alpiraz et al, 2001). In other words if a subset of a choice set is omitted from the model all together will not change parameter estimates systematically (Hausman and McFadden, 1984; Green, 2008). Different model specifications like the nested logit models (Green, 2008; Hensher, Rose and Green, 2005) and the random parameter models (Green, 2008) have been developed to relax this assumption.

5. Application and Survey Design

In the subsequent sections the choice experiment application, the contingent valuation and the survey instrument are presented.

5.1 Choice experiment design

The good to be valued in this choice experiment is the revision of wetland management practices. The key objective is to achieve and maintain "*good water* status". "Good water status" ensures sufficient water of good quality for humans and the environment for today and the future. In this direction, designations and actions are ought to be implemented in order to maintain good water quantity in lakes, spring and aquifer and to sustain as many ecological and landscape functions as possible. A package of means includes the followings:

1. Restrict peat land drainage in the groundwater area
2. Expansion of the conservation area and compensation when legally required
3. Restoration (technical solutions) of peat lands, groundwater and lakes level

Policy under consideration is characterized by 5 different management attributes. Attributes are chosen based on literature reviews and focus group discussions with local stakeholders and with experts.

Implementation of the revised water management is anticipated to contribute positive in water quantity of groundwater aquifers and thereby water level of lakes. Proposed policy options will help lakes to restore their water level. A future possible deterioration is avoided and current state of water is at least sustained. Environmental improvements would also result to an increase in recreational values. In the case where no measures are taken water quantity and recreation will move to a lower level. It is also expected that wider public derive a range of benefits other than environmental from the services that wetland provides (Portney, 1994).

In the literature it can be found many choice experiment studies that have included social and economic attributes into their analysis to examine the benefits that people derive from such factors. Morrison et al. (1998) in Macquarie Marshes, a major wetland in New South Wales, Australia apart from the non-use environmental values provided by the wetland also estimated values community places on preventing job losses. Similarly, Othman et al. (2004) to evaluate the management of Matang Mangrove Wetlands in Perak State, Malaysia, estimated the implicit price of the employment of local people in wetland's based extractive industries. Bennett et al. (2004) employed a choice modeling in Australia, to value the benefits associated with the avoid loss of people from rural and regional areas that may result from environmental protection measures. Thus this way it was being captured the trade off between environmental protection and income sources for local people.

Following findings of the literature, the impact of socio-economic attributes into the process of environmental decisions is being examined through a total land income attribute. Respondents were informed that in the absence of a revised management, environmental degradation may result to a decline in the popularity and the number of visitors to Rokua area, so income from tourist activities will tend to decline. As a result land income (total income opportunities) is expected to get restricted. On the other hand, implementation of proposed scheme will moderate restrict activities associated with lodging and peat harvesting but at the same time might render this area an attractive tourism (geo-tourism and/or eco-tourism) location in Finland. Thus in the mid-term there is a probability that the increase of income opportunities from tourism will cover the loss of income from the moderate restriction of lodging and peat harvesting. So there is a probability that total income will remain unchanged i.e. at current level.

Table 2: Wetland management attributes and levels used in the CE

Attribute	Definition	Management Level
Water Quantity	This attribute refers to the total quantity of water available in groundwater aquifer, lakes and spring.	**Increased**: most of the lakes have restored their water level
		Same as now: some lakes have water quantity problems. Current state of water is sustained.
		***Limited**:* water quantity has been considerable declined. The last alternative reflects what is expected to happen in the absence of revised management in the future.
Recreation	This attribute refers to the sum of all values (direct and indirect) derived from recreational activities.	**Increased:** environmental improvements result to an increase in recreational values.
		Same as now: current levels of recreational values are sustained.
		***Low**:* This is the case where no measures are taken. As a result of environmental degradation in the absence of the revised management, recreational values are going to decline
Total Land Income	This attribute refers to the **total** income opportunities for the local people emerging from economic activities of **lodging, peat harvesting** and **tourism** industry based in Rokua area.	**Same as now:** Total income will maintain current conditions, will remain unchanged.
		Restricted: Total income opportunities will get restricted
Investment on Research	This attribute refers to the scientific research to better understand long-term environmental changes in Rokua.	**High**: More Resources
		Medium: Current Resources
		Low: Stop current research
Price	One-off payment	10€, 50€, 100€, 200€

Levels in italics indicate the status quo levels of each attribute.

At the moment scientific understanding of long-term environmental change is incomplete and uncertainty is surrounding both the ultimate damage likely to be occurred if no action is taken and the extent of the possible environmental gains after a revision of the existing water management. Arguing that scientific uncertainty is not inherited to the system, opposite to other elements of uncertainty, like climate change, it is been assumed that improved investment on research can reduce the overall amount of un-expectability. To capture the value of scientific information an attribute called investment on research, referring to the scientific research to better understand long-term environmental changes in Rokua is included in the analysis. Individuals were informed that currently there is limited understanding of complex hydrological functions and of interrelationships between different users and their potential impact on water dynamics. Improved scientific knowledge could reduce the overall level of uncertainty regarding future environmental gains from the revision of the management thus in a sense the higher is the level of scientific research the more certain is the expected outcome of the revised management.

The attributes and their possible levels, in the mid-term horizon (5 to 10 years from now) depending on whether a policy is implemented can be seen in Table 2.

A large number of unique wetland management scenarios can be constructed from this number of attributes and levels. Experimental design techniques were employed in SPSS to obtain an orthogonal design (Louviere et al., 2000 and Hensher et al., 2005). Orthogonal design implies that the variations of the attributes of the alternatives are uncorrelated in all choice sets. In this case orthogonal design consisted of only main effects in 32 pair-wise comparisons of alternative wetland management scenarios. These were randomly blocked to 4 different versions, each with 8 choice sets. An example of a choice card is presented in Table 3.

Table 3: Sample choice set.

Assuming that the following three wetland management scenarios were the only choices you had, which one would you prefer?			
Attributes	Scenario A	Scenario B	Scenario C: Status quo
Water Quantity	Increased	Same as now	Limited
Recreation	Same as now	Increased	Low
Total Land Income	Restricted	Restricted	Restricted
Investment on Research	High	Low	Medium
One-off Payment	100	50	None
I prefer (Please tick as appropriate)	Option A	Option B	Option C

Each set contained two different wetland management scenarios and an option to select neither scenario. Scenarios A and B are characterized by a change in attributes with respect to the status quo alternative. The ‘opt out’ option can be considered as the status quo baseline alternative whose inclusion in the choice sets is instrumental to achieving welfare measures (Bateman et al, 2003). Status quo situation reflects what is expected to happen in the absence of revised management in the future. In the status quo alternative no payment required because no management is implemented.

5.2 Contingent Valuation Question

Complementary to the choice experiment a contingent valuation question and a split-sample survey employed to investigate individuals’ behavior in a setting of uncertainty with respect to the damage level in the absence of the revised water management.

Most of the studies in the valuation literature aim at determining the willingness to pay for water services considering single changes i.e. from a lower to a medium or higher level water quality. Thus there is a fundamental assumption behind that survey design that all different scenarios presented can be achieved with certainty so respondents can reveal their underlying preferences upon certain outcomes (Roberts et al., 2008). Yet there few studies that have incorporated issues of uncertainty regarding the exact nature of damage under the status quo as well as the timing and the extent outcomes of the proposed environmental policies.

Johansson (1988), in a contingent valuation study in Sweden presented some preliminary results on the consistency of willingness to pay measure for public goods in an uncertain world. Respondents were asked of their willingness to pay for four different programs that each would save all or some of the species. The result of one of the program was uncertain, respondents were informed that was a 50% chance the program would save all species and 50% would save every second species. The remaining programs would save 50%, 75% and 100% respectively. Macmillan et al. (1996) employed a contingent valuation method to estimate willingness to pay of the Scottish population for uncertain recovery and damage scenarios from reduced acid rain deposition in the semi-natural uplands of Scotland. Approximately 1000 households were sampled by mail. In order to incorporate uncertainty with respect to the damage level in the absence of further reductions in emissions recovery it has been used a split-sample survey format presenting six alternative ecosystem recovery levels and damage levels scenarios. Average household WTP, elicited using a dichotomous choice format, for abatement of acid rain ranged from 247 pounds to 351 pounds depending on the scenario.

Uncertainty introduced in Rokua case study through the use of subjective probabilities, i.e. in the absence of any better information there have been assigned equal probabilities to the mutually exclusive outcomes of water states[76] (State A: High, State B: Good, State C: Moderate, State D: Poor, State E: Bad). Following work of MacMillan et al. (1996), in the first sub-sample respondents were informed that in the absence of a revision of water management there is 50% chance that water quantity will remain at current levels State (C) and 50% chance level to go to State (E), this implies an expected future damage State (D), while in the other sub-sample respondents were informed that water quantity will be with certainty at State (D). In both cases the revision of water management would result in a certain level of improvement.

The aim is to test whether or not utility will be higher for a management option when the expected future damage under status quo will be moderate but with a possibility that may be minimal, than for a programme when future damage under status quo will be moderate for certain. Macmillan et al. (1996) concluded that when individuals faced with future environmental damage appear to be risk-averse. On the contrary Kahneman and Tversky (1979) presented a body of empirical evidence that individuals are risk-seekers when financial losses are in prospect. Appealing to both papers, the contingent valuation question is employed to be able to investigate risk behaviour of local's residents and to observe how and if the valuation result changes when respondents are aware of the uncertainty regarding environmental losses with respect to the status quo level.

5.3 The Questionnaire

As it has been already been mentioned in Section 4, both techniques employed in this study require a carefully designed survey. The main goal of the questionnaire is to try to elicit information about environmental preferences from individuals through the construction of hypothetical but realistic scenarios of water management practices that involve an improvement in environmental quality (Koundouri, Lectures Notes). The complete questionnaire covered a number of topics and was divided into 5 sections, see Table 4.

[76] For the presentation of water states has been used the visual presentation of water provided by WFD:

HIGH	GOOD	MODERATE	POOR	BAD

Table 4: Questionnaire structure

Section A	Presenting the problem	Site description Scientific facts Good to be valued Attributes to be valued Scenarios
Section B	Choice experiment questions	8 sets of choice cards
Section C	Debriefing Questions	Questions to explain why respondents were or were not WTP
Section D	Environmental Behaviour Questions	Questions that reveal environmental consciousness
Section E	Contingent Valuation Question	Question to examine risk behaviour
Section F	Socio-economics questions	Among others age, education, job and income

The development of the pilot survey instrument took place over a period of almost one year and involved initially focus groups discussions, face to face interviews with local stakeholders and extensive discussions with experts. Discussions with local stakeholders revealed people's understanding of the issues related to the management of water resources and services in Rokua. Stakeholders from forestry, peatland industry, 2nd house owners, local residents and service providers, were asked general questions whether they are familiar with environmental conditions of water resources in Rokua and the issues related to it, i.e. land use issues and climate change and finally whether and how they value environmental goods or services that Rokua esker provides. During discussions with experts it was defined the valuation problem, the exact attributes that are being valued and the level to which these attributes can be increased with an implementation of a policy option and to what levels they might fall if deterioration would continue to increase (Koundouri, Lectures Notes).

The beginning of the questionnaire introduced the study area and the issue in question. Estimates are very sensitive on the description of the hypothetical choices individuals make, thereby information respondents have about the environmental good they value is determine their quality. The answer sheet was attached in a text in which individuals were provided with an accurate and clear description of attributes and their associate levels with the policy under consideration. Scientific facts and visual aid i.e. colour photographs and simplified graphs were employed to help respondents understand the situation in Rokua and the conditions of the choice scenarios that are being asked to value.

The aim of the questionnaire is to select sufficient data for the purposes of the analysis. To obtain more information, the questionnaire contained debriefing questions and questions that reveal environmental consciousness of the respondents. Also socio-economics questions were asked (age, gender, income categories, occupation and educational attainment) to obtain individuals' attributes. All these questions intend to provide additional information that could affect each respondent's choice on the level of WTP.

6. Analysis of data

The pre-testing survey was carried out during April 2011. A total of 37 face to face interviews were conducted. A face to face interviewing process was selected due to the potential advantages of a higher response rate and effective information provision (Perman, 2003). Individuals in complex situation when they are interviewed in person they better understand the required information for the valuation they have to make and are more likely to complete a long survey. Choice experiment data were coded[77] continuously according to the levels of the attributes [0 - Restricted, 1 - Same as Now, 2 - Increased]. Levels of price were entered in a linear form, i.e. as 10€, 50€, 100€, 200€. A summary of respondents' background information such as gender, education level, occupation, tenure status and income is listed in Table 5 and a histogram of environmental consciousness variables can be seen in figure 1.

Table 5: Socioeconomic profile of the respondents, based on non-missing observations

Respondents' Profile		Frequency	Distribution (%)[78]
Gender:	Male	19	51,35%
	Female	18	48,64%
Education Level:	Less than upper secondary school (up to 18 years)	5	13,51%
	Upper secondary school (up to 18 years)	19	51,35%
	University Degree	11	29,72%
	Postgraduate	1	2,7%
Occupation:	Full-time job	1	2,7%
	Part-time job	1	2,7%
	Pensioner	7	18,91%
	Student	26	70,27%
Tenure Status:	Home Owner	10	27,02%
	Renter	27	72,97%
Income:	Less than 10.000 euros	14	37,83%
	[10.000] – [20.000] euros	16	43,24%
	[20.000] – [30.000] euros	3	8,1%
	[30.000] – [40.000] euros	1	2,7%
	[50.000] – [60.000] euros	2	5,40%
	[60.000] – [70.000] euros	1	2,7%

The level of the respondents' environmental consciousness was elicited through questions regarding purchase of organic products, of environmental publications, recycling and donation to environmental charities. These were measured on a four point scale ranging from never to always. From the Likert scores of the environmental behaviour questions, an environmental consciousness index ranging from 0 to 20 is created (Birol et al., 2006). It follows a table with the descriptive statistics based on non-missing values of the pilot Rokua survey. The last two columns of Table 6 refer to the split sample employed for the contingent valuation question.

[77] Different coding, i.e. dummy coding (0,1) and orthogonal coding (-1,0,1) (see Louviere et al,2000), are also going to be examined to check the performance of the analysis before the analysis of the actual survey.

[78] Sum of the percentages may not add up to 100 due to rounding up.

Figure 1: Frequencies of environmental behavior variables

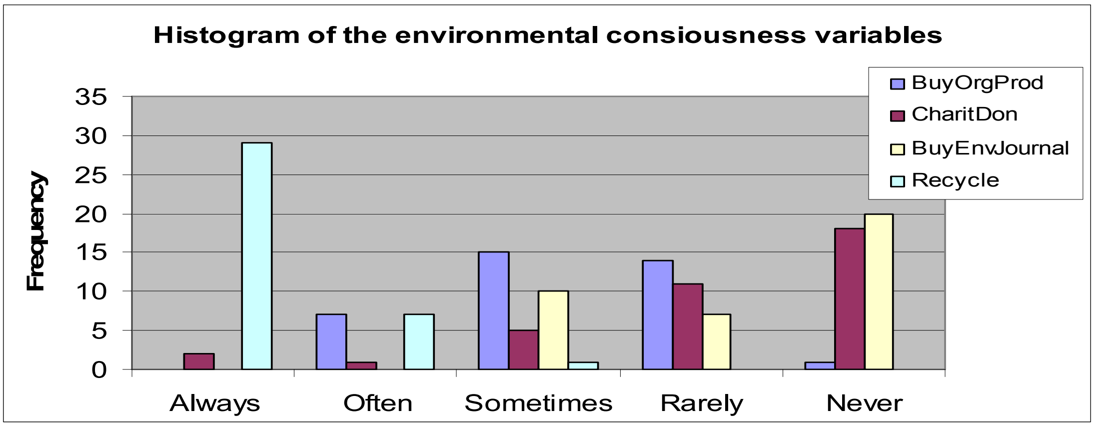

Table 6: Descriptive Statistics of the pre-testing survey sample

Variable	Survey Sample	Sample 1	Sample 2
	Mean (std. dev.)	Mean (std. dev.)	Mean (std. dev.)
Age	34.25 (21.44)	33.94 (21.63)	34.58 (21.90)
Gender (% male)	.513 (.506)	.526 (.512)	.5 (.514)
Children (% with children)	.243 (.434)	.263 (.452)	.222 (.427)
Visited the wetlands	.486 (.506)	.526 (.512)	.444 (.511)
Tenure Status (% home owers)	.270 (.450)	.263 (.452)	.277 (.460)
People in the households	1.68 (.582)	1.82 (.635)	1.55 (.511)
Price (choice experiment)	30 (35.61)	-	-
CV response (% of yes responses)	-	.947 (.229)	.944 (.235)
CV payment vehicle	-	48.42 (33.65)	61.11 (35.29)
Sample Size	37	19	18

Descriptive statistics reveal much information regarding data. 48% of the sample has visited the wetlands mainly for recreational reasons and to a much lesser extent for educational/scientific reasons. From the whole sample only one person holds a 2nd house property in Rokua area and only one person is a service provider. Only 24% of the sample has children, of which only one is dependent. The majority of the sample is students, in terms of occupation only one individual has a full time job and seven individuals are pensioners. Finally the majority of the sample gross households' income lies into the lower annual net income categories. Sample population is homogenous and on average among others is younger and has lower income that Rokua's population. Thus estimates are not representative for the whole population in Rokua.

7. Econometrical Analysis

Econometrical analysis has been conducted with LIMDEP 8.0 NLOGIT 3.0. This part presents some properties of the pilot survey data and some preliminary results. Given that this is not a representative sample of Rokua's population results should be interpreted with care.

7.1 Choice Experiment Results

From the whole sample only four individuals choose neither management option. The main reasons why respondents were not WTP is mostly because they do not have the financial capability to participate and to a lesser extent because they do not believe that the proposed measures will succeed in improving conditions. Most of them agreed that someone else should pay for the management of the wetlands and the restoration of ecosystems but all of them strongly disagreed with the statement: I have no interest for water quantity and quality in the aquifer.

The choice experiment data were analyzed using a multinomial logit model including all the experimental design variables in linear form. The model is specified so that the probability of selecting a particular scenario is a function of attributes of that scenario. Estimates of the regression analysis can be seen in Table 7.

Table 7: Estimates Basic Multinomial Logit

Variable	Coefficient	Standard Error
Water Quantity	.97952533*	.15748047
Recreation	.75020358*	.14224992
Total Land Income	-.00137413**	.17571583
Investment on Research	.17444622**	.12148421
Cost	-.01226514*	.00357471
Log-Likelihood	-224.9661	
R^2	0.28898	
Sample size	296	

* 5% significance level with two tailed test; **Insignificant

The model reported a quite good overall fit. The coefficients of water quantity, recreation and cost are statistical significant at 5% significance level with two tailed test and theirs signs are as expected a priori. Water quantity and recreation are significant factors in the choice of a wetland management scenario and, ceteris paribus, higher level of these attributes increases the probability that a management scenario is selected. The sign of the payment coefficient as it was anticipated is negative and statistical significant, choosing a choice set with higher payment level has a negative effect on utility. Investment on research has a positive sign indicating that scientific values have a positive effect on utility yet is not statistical significant. Total land income coefficient is also statistical insignificant and appears to have a negative effect on utility. This could be partly explained from the fact that the majority of the sample is students who may not reckon income as a significant factor in the choice of a wetland management scenario.

To test the appropriateness of this model specification, a Hausman and McFadden (1984) test was carried out. The IIA property was significantly violated when any of the choice alternatives was dropped from choice sets, indicating that the model does not fully conformed with the underlying IIA property.

To check for the presence of multicollinearity among attributes auxiliary regression tests were conducted where each attributes was regressed on the remaining attributes. Testing for one alternative at a time a total of a 10 auxiliary regressions were estimated. R_i statistic was calculated from R^2 values and compared to the F-critical value with the appropriate degrees of freedom, i.e. $F(3,292) = 2,60$. All R_i statistics exceeded the F-critical value suggesting that attributes are collinear with the remaining attributes and implying that correlation is likely to be significant at α=0,05.

Complementary a correlation matrix based on Pearson moments has been produced to observe correlations between attributes.

Table 8: Correlation matrix for experimental design variables

	Water	Recreation	Total Land Income	Investment on Research	Cost
Water	1.00000				
Recreation	.75000	1.00000			
Total Land Income	.43301	.43301	1.00000		
Investment on Research	.54772	.56993	.31623	1.00000	
Cost	.51619	.51619	.29802	.37697	1.00000

Again, it can be seen that attributes are moderate correlated. A cut-off of 0.8 has been selected to see if collinearity will impose a problem to the analysis (Heshner et al. 2005). All correlations are below that limit apart from correlation between water and recreation attribute which is very close to the margin of 0.8. The presence of collinearity can be partly explained due to the poor sampling procedures. Different number of individuals is being exposed to different blocks of the design. It appears that orthogonality has been lost due to wrong allocation of decision makers to versions of the choice sets (Heshner et al., 2005).

The main purpose of a choice experiment is to estimate the welfare effects of changes in the attributes. For the linear utility function, the marginal rate of substitution between two attributes is the ratio of their coefficients (Birol et al.,2006) and the marginal willingness to pay for a change in attribute is given by: $MWTP_i=-\beta_i/\beta_{cost}$

In calculating WTP both attributes must be statistical significant otherwise no meaningful WTP measure can be established. WTP has been calculated from the cost and water quantity and recreation attributes which are all statistical significant using the Delta method in Limdep. In particular it was estimated that marginal WTP for one economic year is 79,86 (s.e.19,49) euro/respondent for improvements in water quantity and 61,16 (s.e. 19,24) euro/respondent for an increase in recreation. Results have to be interpreted with care and are here mostly for illustrative purposes. Note that the aforementioned implicit prices do not provide estimates of compensating surplus for the alternative management scenarios over the status quo. Given the poor performance of the estimated model it was decided analysis to be restricted to the production of implicit prices for each attributes and not to estimate consumer surplus measures.

7.2 Contingent Valuation Results

Overall, in the contingent valuation question only two persons, one in each sub-sample, are not willing to make a payment for the revision of water management. The collected survey data have no variation and it was not possible to incorporate them into a regression analysis. Due to poor sample, estimates can not be produced and thus analysis is restricted on presenting only average willingness to pay within sub-categories based on socio-economic characteristics of the individuals, Table 9.

Table 9: Average WTP for the contingent valuation questions

Average WTP within each sub-category (€/respondent)	**Uncertain future environmental damage**	**Certain future environmental damage**
All	**48,42**	**61,11**
Male	41	57,7
Females	56,66	64,4
Children, Yes	62	40
Children, No	55,45	67,14
Visit, Yes	49	47,5
Visit, No	47,77778	72
Income, ≥10.000 €	30	68,75
Income, [10.000] – [20.000] €	66,25	60
Pensioner	53,33	40
Student	46,15	64,61

Average WTP is greater for the certain future environmental damages scenario, 61.11 €/respondent than for the scenario with uncertainty in future environmental losses, 48.52 €/respondent. WTP based on gender showed that female respondents were willing to pay more on average than male for water improvements in both scenarios. Yet the sample is so homogenous and small that is not possible to isolate WTP for different segments of the population and as can be seen, no meaningful comparisons can be made.

8. Discussion and Concluding Remarks

This study presents some preliminary results from a pre-testing pilot survey of a choice experiment undertaken on Rokua esker, Finland. The purpose of the choice experiment was to investigate the local public's preferences for alternative wetland management scenarios, defined by their impacts on water quantity, recreation and total land income and by improved scientific information.

The main purposes of the pilot survey is to verify that the questionnaire logic is correct and to ensure that information given to the respondents is comprehensive, easy to understand and presented in such way that the respondents' cognitive abilities are not strained, nor that they are encouraged to indulge in heuristic behaviour (Fischoff and Furby, 1988). Pre-testing suggested that respondents would have no difficulties with the environmental changes caused by the revision of water management. This can be verified from the high response rate. No changes have been made to the questionnaire and interview procedure in Rokua is being continued with this survey instrument. The main sample it is expected to be consisted from 300 individuals, local residents and visitors.

Econometrical analysis employing a multinomial logit model suggests that water quantity and recreation are significant factors in the choice of a wetland management scenario. Yet given the quality of the sample the estimates must be seen with care and are useful just to obtain a general idea before the main survey data are analyzed.

The main limitation of this study arises due to the fact that the sample is small, homogenous with no variation. In this point where the aim of the analysis is mostly to evaluate how respondents react to the questionnaire and observe some general trends this is not a problem. However analysis of the main choice experiment must be based on a randomly selected sample of the relevant population.

When the data have been collected a further econometrical analysis will be made to be to produce estimates representatives for the Rokua population.

In terms of econometrical analysis of the pilot survey only a linear form of the utility has been tested, however in the analysis of the main survey different conditional model with logarithimic and linear specifications will be estimated to observe which provide one the highest value of log-likelihood function (Birol et al.,2006). Also an alternative specific constant (ASC) will be included to capture the effects of moving from status quo that was not possible to include it in the analysis with the pilot survey data. Also, various interactions between socioeconomic variables and alternative specific constants and attributes are going to be estimated. Introduction of such interaction terms accounts for heterogeneity in the sample and uncovers whose welfare is affected by the changes in the environmental state (Boxall and Adamowicz, 2002).

Results of the pilot survey indicated that the model failed to meet the underlying assumption of the independence of irrelevant alternatives (IIA property). If main sample reject this assumption as well, different model that relax this property should be examined like random parameters models and nested models (given that the sample will be randomly selected and heterogeneous enough to be able to classify population to different segments). Also employment of such models will enable us also to examine the existence and the sources of preference heterogeneity across respondents see studies of Birol et al. (2006) and Milon and Scrogin, (2006).

Further analysis of the main survey is expected to reveal informative results. Benefits generated from water management will help shape future land use and ecosystem protection policies. Also the value of scientific information on climate change in an uncertain environment if present will be isolated.

Acknowledgments

We acknowledge the financial support by the Groundwater and Dependent Ecosystems: New Scientific and Technological Basis for Assessing Climate Change and Land-use Impacts on Groundwater (GENESIS). The GENESIS project (Contract number: 226536) is funded under the thematic area Environment (including Climate Change) of the Seventh Framework Programme of the European Community for research, technological development and demonstration activities (2007-2013).

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Integrating visitors' motivations for planning tourism events: An empirical research

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Abstract
Event tourism constantly gains the interest of many researchers since in most cases interrelates natural settings, visitors' motivations and various stakeholders within the tourism system. As a direct consequence, it highlights the need for elaborating on new tourism trends by searching the needs and wants of visitors. The purpose of this study was to identify respondents' motivation factors and define destination attributes in view of establishing targeted tourism policies driven by consumers. Factor analysis was applied so as to determine pattern of correlations and uncover latent variables. Principal component analysis (PCA) with Varimax rotation method was performed on the importance ratings of the 25 motivation factors identified in the instrument development process. Based on factor scores, cluster analysis was then implemented so as to segment the relevant tourism market. M***otivation factors, travel behaviour isuues and sociodemographic characteristics*** were used to identify opinion groups that have similar response patterns and share similar properties, desires and expectations when attending tourism events. Discriminant analysis was carried out so as to confirm the validity of the cluster solutions. The research findings have management and marketing implications so as to plan and promote sustainable and cost effective tourism practices in light of future direction and destination development.

Keywords: events, market segmentation, customers

1. Introduction

Event tourism, an approach in which planned events are designed specifically to attract tourists to a destination, foster a positive destination image, and contribute to other destination -related promotions, has become an integral part of destination tourism development (Getz, 2008). Getz and Wicks (1993) define event tourism as the systematic planning, development and marketing of festivals and special events as tourist attractions, catalysts, and image builders. Supportively, special events minimise environmental and social impacts and they can contribute to sustainable development as well (Uysal and Gitelson, 1994). Moscardo (2007) claims that the existing tourism literature on festivals and events is dominated by four main topics including economic impacts, audience analysis with a view to improving marketing and service quality, the management of events with a particular concern to enhance marketing and service quality and broader event impacts as perceived by residents. Furthermore, the destination development engendered by an event is largely driven by the attendance it is expected to generate (Faulkner *et al*., 2000). Thus, the promotion and marketing of tourism events is a key area of interest due to its complex nature. The identification of visitors' motivations to attend tourism events has been subject to research for many scientists (Shanka and Alamiyo 2012; Getz 2008; Spaks 2007; Taylor and Shanka, 2008; Robinson and Gammon, 2004; Raybould 1998; Formica and Uysal, 1998;

Crompton and McKay 1997; Backman et *al*., 1995; Uysal and Gitelson, 1994; Lee, 1994; Uysal and Wicks, 1993).

The purpose of this study was to decode vistors' motivation factors for attending tourism events by applying factor-cluster analysis. Consequently, market segments can be identified and viable tourism plans can be put into practice in light of effective destination management, economical growth and sustainable use of natural resources. As the field of event tourism continues to develop, the need for identifying the motivation factors of tourists remains a crucial issue in meeting their needs and wants and keeping them satisfied in view of word of mouth reputation and increased visitation rates. Beerli and Martin (2004) clearly state that motivation is the need that drives an individual to act in a certain way to achieve the desired satisfaction. With the ever increasing diversity and selection of tourism products in the tourism market, it is not surprising to see a growing interest in identifying factors and variables which might affect tourism product choice. Market segmentation is justified on the grounds of achieving greater efficiency in the supply, promotion, and delivery of purpose-designed products that identify demand, satisfy the needs of target groups and increase cost effectiveness in the marketing process (Park & Yoon, 2009). In this perspective, Middleton (2002) defines market segmentation as the process of dividing a total market such as all visitors, or a market sector such as holiday travel, into subgroups or segments for effective management purposes. Segmentation effectiveness depends on arriving at segments which are measurable, accessible, substantial, actionable and differentiable (Kotler et al., 2001).

Mansfeld (1992) claims that an analysis of the motivational stage (which generates the whole process) can reveal the way in which people set goals for their destination-choice and how these goals are then reflected in both their choice and travel behaviour. It seems necessary, then, to expand studies which enable providers and managers to define potential market segments which perceive and use the natural resource differently seeing the beach as a heterogeneous market rather than a homogenous entity. Tourism products that involve visitors in an enjoyable journey enriched with quality services, experience, knowledge and nature friendly recreational activities can benefit all tourism stakeholders. The "new tourism" approach demands new products and destinations which involve the use of information, marketing and sales technologies (Alegre & Cladera, 2006).

2. Methodology

2.1 Principal Component analysis

The research took place in the coastal zone of the north part of Maliakos gulf (Atalandi city) during a food and wine tourism event which is organized in summer months every year. In the research, 494 questionnaires were selected by using face to face interviews. Principal component analysis (PCA) with Varimax rotation method was performed on the importance ratings of the 25 motivation items. The analysis generated eight factors explaining 65.85 % of the total variance. A KMO test yielded a measure of 0,785, demonstrating that the distribution of values in the initial measure of motivation dimensions was adequate for conducting factor analysis. Bartlett's test of sphericity produced a x^2 of 8733.314 at a significance level of 0.000. Factor loadings of all relevant variables in the rotated factor matrix were clearly related to only one factor each. The internal consistency of the factors, measured with Cronbach's a indicator, showed good reliability with the scores ranging from 0.65 to 0.81. The resultant factor groupings of information sources were meaningful and allowed us to capture the amount of total variance in explaining information sources. For each extracted factor a “name” or a “label” should be assigned which depicts the common sense or characteristics among the included factors (Kim et al., 2006). Factor 1, labelled “event attractiveness” mainly comprised with items such as tasting famous local traditional products, the fame of the event, the hospitality provide and the destination itself (the whole atmosphere during the event). Factor 2, labelled “socialization” included five statements describing the respondents’ intended social experiences and interaction with the tourism event. Factor 3, labelled “personal satisfaction” involved statements that are in direct connection with opportunities for getting enthused, having fun and seeking internal balance and equilibrium. Factor 4 relates issues such as enhancement of local economy during the event, helping the development of original local products and finding business opportunities. Hence, such factor was labeled “socioeconomic growth”. Factor 5, labelled “sustainability” consisted of statements on ensuring and seeking ways for sustainable and wise use of natural sources in terms of tourism events. Factor 6, labelled “escape” comprised of three statements describing the impact of respondents’ disposition to get away from routine, the positive mood and feeling during the event as well as the experience of a change in their daily life. Factor 7, labeled “knowledge seeking” included three statements concerning the learning of cultivation and production of traditional products, its nutrient value and the positive effects on health that may cause. Finally, factor 8, labelled “family togetherness,” included two statements describing the opportunity to spend time with the family and the transmission to family members the meaning of locally grown products and the positive impacts in local communities theory the event.

2.2 Cluster Analysis

Cluster analysis was conducted on the 25 impact statements in an effort to identify groups of residents with similar response patterns. For the cluster analysis, a hierarchical technique was first applied using Ward’s method with squared Euclidean distances, since the *a priori number* of segments was not known beforehand. Thereafter, in view of identifying different groups of respondents and visitor segments based on motivations, a K-means cluster analysis (non hierarchical approach) was employed. The results showed a two to five cluster solutions. Ultimately, the three-cluster solution seemed to provide the most interpretable and applicable results. The K-means clustering method produces results that are less susceptible to outliers in the data, the distance measure used, and the inclusion of irrelevant or inappropriate variables (Hair *et al.*, 2006). Individuals were clustered in such a way that those within each cluster were more similar to each other than those in other clusters, thereby creating a situation of homogeneity within clusters and heterogeneity between clusters. To determine the importance of the extracted factors the means for each of the eight motivation factors concerning the defined clusters were calculated (Table 1). In order to determine how well the discriminant function classified the respondents, the classification matrices were examined and the hit ratio, or the percentage correctly classified was identified. The classification matrix of respondents was used to determine how successfully the discriminant function could work. Almost all (97.5%) of the 494 grouped cases were correctly classified, representing a very high accuracy rate. Specifically, “event seekers” (96.04%), “escapers” (99.12%) and “learners” (97.55%) were correctly classified into their respective groups (Table 2). In order to further identify the profile of the three clusters, each cluster was cross-tabulated with external variables such as the tourists’ socio-economic characteristics and travel behavior aspects (Table 3).

2.2.1 Profiling the clusters

The "event seekers" visitors represented the 35.83% of the sample (n=177). As shown in Table 1, among the three cluster groups, this cluster appeared to have the highest mean score on "event attractiveness factor". This cluster group placed great importance on characteristics that make the tourism event appealing and interested for attendance. They had an annual income of 1001-1500€. The length of stay for this cluster was more than 3 days. Members of this cluster had visited the destination more than two times in the past to attend the tourism event. The second identified cluster, the "escapers" representing the 22.87% of the sample (n=113) was found to have the largest mean score on "escape" dimension. This segment was discriminated by the importance ratings of items all related to opportunities to avoid every day routine, feel nice, have fun and experience a change by attending event tourism. They, also, had an annual income of 1501-2000€. The length of stay for members of this cluster was 2-3 days whereas they had visited the area in the past ranging from two to three times. The third segment, the "learning" visitors, comprised of 41.30 % of the sample (n=204). It appeared to have the highest mean score in *"*knowledge seeking/learning*"* factor. The results of this study showed that members of this segment were more likely to depict a disposition to learn about aspects related to cultivation and production of the food and wine presented in the tourism event. They, mostly, had an annual income of 500-1000€. The length of stay for members of this cluster was one day. Respondents of this cluster had visited the destination for first time.

Table 1: Motivation factor means among clusters

Factor	Cluster 1 Event seekers (n=177/35.83%)	Cluster 2 Escapers (n=113/22.87%)	Cluster 3 Learners (n=204/41.30%)	Total Mean	F value	Sig
Event attractiveness	4.38	3.47	3.89	3.91	41.34	0.000
Socialization	4.01	3.23	3.77	3.67	38.03	0.000
Personal Satisfaction	3.11	3.37	3.97	3.48	21.86	0.000
Socioeconomic Benefits	2.99	3.21	3.45	3.22	68.33	0.000
Sustainability	3.01	3.43	3.75	3.40	49.98	0.000
Escape	3.43	3.87	2.57	3.29	57.01	0.000
Knowledge seeking/ Learning	2.78	3.28	4.01	3.36	33.47	0.000
Family togetherness	3.17	2.77	2.54	2.83	37.71	0.000
Note: 1=not at all important, 5=very important						

Table 2: Evaluation of cluster formation by classification results

Cluster number of Case	Predicted Group Membership			Total
	Event seekers	Escapers	Learners	
Event seekers	170 (96.04%)	3 (1.70%)	4 (2.26%)	177 (100%)
Escapers	1 (0.88%)	112 (99.12%)	0 (0.0%)	113 (100%)
Learners	2 (0,98%)	3 (1.47%)	199 (97.55%)	204 (100%)

Table 3: Sociodemograpic characteristics and travel behavior

	Event seekers (177)	Escapers (113)	Learners (204)	Total (494/100%)	Chi square (p<0.05)
Gender					44.85
Male	97	78	123	298	
Female	80	62	81	196	
Income					33.77
500-1000	33	25	89	147	
1001-1500	77	31	40	148	
1501-2000	41	48	18	107	
2001+	26	9	57	92	
Profession					37.10
Private sector	90	24	62	176	
Public sector	41	57	47	145	
Freelance (self-employed)	46	32	95	173	
Educational level					29.54
High school graduate	58	71	63	192	
University degree	99	28	54	181	
Post graduate studies	20	14	87	121	
Length of stay (days)					21.12
1	54	13	94	161	
2-3	45	76	52	173	
3+	78	24	58	160	
Previous Visits					27.17
Never before	27	23	92	142	
1-2 times	62	79	39	180	
More than 2 times	88	11	73	172	

3. Discussion and conclusions

Planned events are spatial–temporal phenomenon, and each is unique because of interactions among the setting, people, and management systems—including design elements and the program (Getz 2008). Consumer satisfaction with a tourist attraction is enhanced with visitor participation (Pearce 1991). Hede (2007) clearly states that research on event evaluation is currently focused on amalgamating the economic, social and environmental forms of evaluation into one framework. However, it is clear that there is now an increasing interest in moving away from a preoccupation with the event as a discrete entity towards a much broader conceptualization of festivals and events as phenomena embedded in a multiplicity of spatial, socio-cultural, political and environmental contexts (Quinn, 2009).

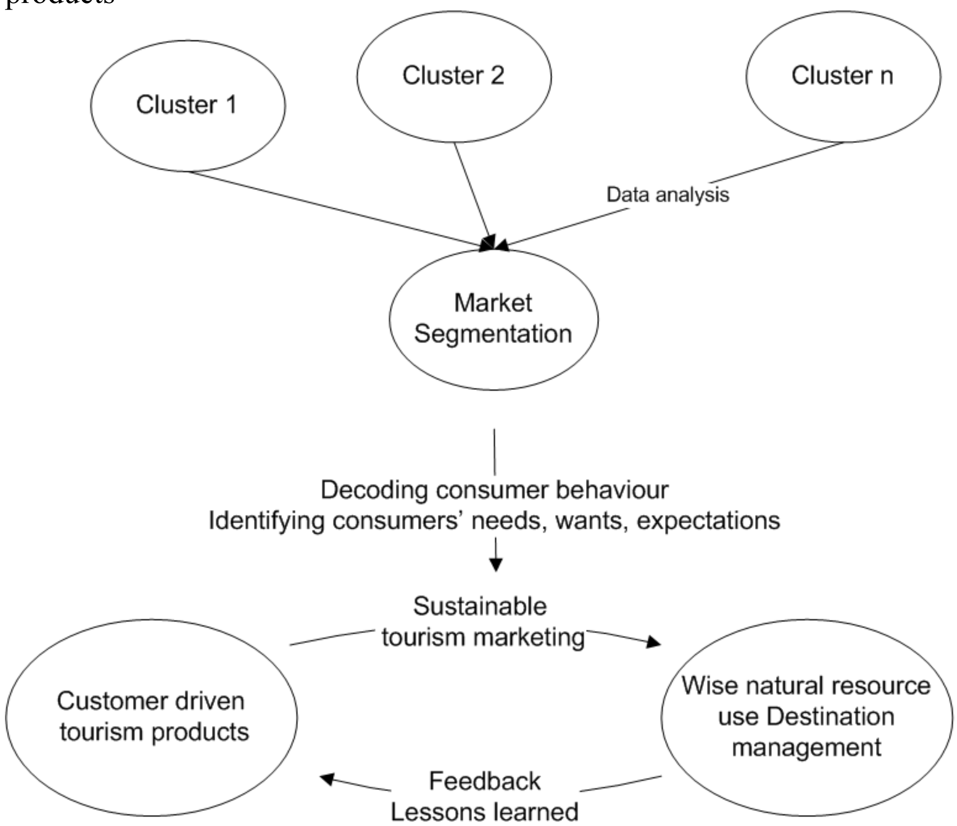
A fundamental reason for understanding motives lies in their close relationship with satisfaction. Motives occur before the experience and satisfaction after it (Crompton and McKay, 1997).

Perceiving what customers value most and the extent to which these valued attributes can be interpreted into applicable event tourism plans are important determining factors for achieving coherent strategic policies which offer a great challenge of placing tourism planners in the role of social change agents (Lew, 2007) The identification of factors that shape travelers behavior provides an advantageous way in determining the orientation and the content of the proposed tourism products. The role of host community and the active participation of the local residents are considered fundamental factors in achieving the desired improvements and tourism accomplishments. Figure 1 shows the way that market segmentation studies interrelate with effective tourism plans driven by customers. Openness to change, willingness to learn, self development and assessment of local society improves the performance levels of the system. The foregoing analysis is deemed crucial in decomposing visitors' needs and wants since they feature largely in their responses.

Keeping tourism products customer oriented the local society should expect reduced unemployment, extended tourism seasons as well as income and revenue generation. Host community should assign social value to the tourism endeavours and enable its contribution to the anticipated market expansion and sustainable growth. Robertson *et al.* (2007) argue that uniqueness of events that engage memory stimulation and provide entertainment could contribute to successful outcomes. Thorough management of the tourism event of interest or in question may advantageously employ multivariate or multidimensional methods to elicit motivations and/or preferences and uncover the dynamics that affect the destination selection process of consumers. Customer driven tourism products are critical to enjoy long term growth since they provide flexibility and demonstrate responsive character. They are designed to add value in coastal sites as sources of sustainability and gain customer satisfaction which is a "cumulative measure of total purchase and consumption experience" (Anderson *et al.,* 1994). Tourism organisations attempting to attract visitors for tourism events ought to integrate motivation factors, key behavioural characteristics and the appropriate sociodemographic characteristics in the decision making process. Managers and spatial planners should incorporate core event tourism features into effective and applicable marketing plans since various predicted needs and wants of visitors can loosely be included in market segmentation studies and relevant models. In particular, value may be gained by emphasising the "event attractiveness" features that included in the analysis. Advertising campaigns that promote the event experience may also be of value to the relevant tourism system. Focusing on the "escape" factor through emphasizing the opportunity to relax and enjoy a tasting experience and a change in their daily life may find vistors delighted and satisfied. In addition, by seeking knowledge during the event tourism may find tourists interested in meeting wine makers and producers of traditional products and learn about the processes that follow to create and launch their goods.

The purpose of this research was to define market segments derived from respondents' judgments so as to advance thorough event tourism marketing. Emphasis has been put on examining separately the opinion groups obtained through cluster analysis so as to analyze the influence of market heterogeneity and bring out themes and trends among visitors. The results showed that there are statistically significant elements among the defined clusters concerning diverse travel motivations, behavioral factors, and sociodemographic characteristics. By integrating findings into applicable tourism policy and getting insights from respondents the efforts to formulate a clear direction concerning tourism development and the relevant management plan will largely help to make matters work and get the things done.

Figure 1: The interrelations among market segmentation and customer driven tourism products



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Προσδιορισμός των παραγόντων απόδοσης οικονομικής αξίας στη θαλάσσια βιοποικιλότητα

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Περίληψη
Η παρούσα έρευνα στοχεύει στη διερεύνηση των σχέσεων μεταξύ της ανθρώπινης στάσης απέναντι στη θαλάσσια βιοποικιλότητα. Ειδικότερα, γίνεται προσπάθεια να καθοριστούν οι παράγοντες που επηρεάζουν την προθυμία πληρωμής των ατόμων για τη διατήρηση της θαλάσσιας βιοποικιλότητας. Για αυτό το λόγο διεξήχθη έρευνα με προσωπικές συνεντεύξεις και τη βοήθεια ενός δομημένου ερωτηματολογίου σε 200 κατοίκους των πόλεων του Βόλου και της Θεσσαλονίκης. Η έρευνα δομήθηκε σύμφωνα με τις αρχές των ερευνών της μεθόδου υποθετικής αξιολόγησης (Contingent Valuation Method), ενώ η διερεύνηση των περιβαλλοντικών αντιλήψεων των πολιτών πραγματοποιήθηκε με τη βοήθεια της κλίμακας NEP (New Ecological Paradigm). Η εξαγωγή των αποτελεσμάτων έγινε με την εφαρμογή Ανάλυσης σε Κύριες Συνιστώσες (PCA) σε συνδυασμό με τη χρήση ενός μοντέλου λογιστικής παλινδρόμησης (Logit regression). Σύμφωνα με τα αποτελέσματα η περιβαλλοντική συνείδηση των ατόμων επηρεάζει την προθυμία πληρωμής τους για τη διατήρηση της θαλάσσιας βιοποικιλότητας. Ενώ, ταυτόχρονα, κοινωνικοοικονομικές μεταβλητές, όπως το εισόδημα, αλλά και απόψεις των πολιτών για τη σημασία της θαλάσσιας βιοποικιλότητας επηρεάζουν την προθυμία πληρωμής τους για τη διατήρησή της. Τέλος, η μέση WTP υπολογίστηκε στα 43,8€.

Λέξεις κλειδιά: Οικονομική αξία, θαλάσσια βιοποικιλότητα, NEP κλίμακα, διατήρηση βιοποικιλότητας.
JEL Κωδικοι: Q29; Q50; Q51; Q57; Q51

Abstract
This study primarily attempts to understand people's attitude towards marine biodiversity. Specifically, it aims to explore the factors influencing people's willingness to pay (WTP) for marine biodiversity conversation. For this reason a face-to-face survey of 200 respondents randomly selected residents of Volos and Thessaloniki was carried out. Respondents' environmental concern was explored with the help of the New Ecological Scale (NEP). For this purpose, a Principal Component Analysis (PCA) together with logistic regression was used. We extract three factors (anthropocentric, human and nature, growth and limits) and explore their influence on respondents' WTP. According to the results there is a relative importance of components of environmental concern in determining marine biodiversity conservation preferences, as well as individuals' willingness for protecting them. Various demographic variables together with the extracted factors show a strong impact on WTP and the specific amounts stated. Income, importance of marine biodiversity for ecological balance influence positively people' WTP for biodiversity conservation.

Keywords: Economic value, marine biodiversity, NEP scale, biodiversity conservation.
JEL Classifications: Q29; Q50; Q51; Q57; Q51

1. Εισαγωγή

Η βιοποικιλότητα συμβάλει ουσιαστικά στην ευημερία των πολιτών παρέχοντας σημαντικό αριθμό αγαθών και υπηρεσιών (MA, 2003). Το γεγονός αυτό σε συνδυασμό με την έντονη πίεση που ασκείται στη βιοποικιλότητα, εξαιτίας της ανθρώπινης δραστηριότητας έχει οδηγήσει στη μείωσή της ή ακόμα και περισσότερο στην εξαφάνισή της (Pimm et al., 1995; MA, 2003; Baillie et al., 2004). Ταυτόχρονα, η διατήρηση της βιοποικιλότητας, τα τελευταία χρόνια, αποτελεί το επίκεντρο σχεδόν όλων των πολιτικών για την προστασία του περιβάλλοντος (Sheppard 2006).

Η εκτίμηση της οικονομικής αξίας της βιοποικιλότητας και των ωφελειών που πηγάζουν από αυτή μπορεί να συμβάλει στην υιοθέτηση στρατηγικών για τη διατήρησή της (Bräuer et al., 2006) λαμβάνοντας υπόψη την οικονομική ωφέλεια που θα προκύψει από την προστασία της (Christie et al., 2006). Παρόλα αυτά, η οικονομική αποτίμηση της βιοποικιλότητας αποτελεί ένα αρκετά δύσκολο εγχείρημα, εξαιτίας κυρίως της απουσίας αγοραίων τιμών για τα αγαθά και τις υπηρεσίες που συνδέονται με αυτή. Επιπλέον, κατά την οικονομική αποτίμηση της θαλάσσιας βιοποικιλότητας προκύπτουν επιπλέον δυσκολίες, εξαιτίας κυρίως της διαφορετικότητας του θαλάσσιου περιβάλλοντος. Η απουσία αγοραίων τιμών για τα περισσότερα αγαθά και υπηρεσίες που πηγάζουν από τη βιοποικιλότητα οδηγεί στην ανάγκη της χρήσης μεθόδων εκφρασμένης προτίμησης (stated preference techniques), όπως για παράδειγμα η μέθοδος της υποθετικής αξιολόγησης (Contingent Valuation Method - CVM) (Mitchell and Carson, 1989).

Στις αρχές της δεκαετίας του 1980 άρχισε η χρήση της CVM, με τη βοήθεια της οποίας οι πολίτες εξέφραζαν την προθυμία πληρωμής τους (Willing To Pay – WTP) για τη διατήρηση ειδών υπό εξαφάνιση (Mäler and Vincent 2005). Σύμφωνα με τους Loomis και White (1996) η CVM μπορεί να χρησιμοποιηθεί για την αποτίμηση της αξίας ειδών υπό εξαφάνιση. Ένας σημαντικός αριθμός ερευνών προσπάθησε να εκτιμήσει την αξίας ειδών υπό εξαφάνιση, με τις περισσότερες να εστιάζουν το ενδιαφέρον τους είδης της θαλάσσιας βιοποικιλότητας (Costanza *et al.* 1997; Williams *et al.* 2003; Patterson and Cole 1999; Stevens et al., 1991).

Παρόλα αυτά, πολλές φορές οι ερευνητές ενδιαφέρονται για τι απόψεις και στάσεις των πολιτών απέναντι στο σύνολο της βιοποικιλότητας και όχι μόνο σε συγκεκριμένα είδη. Σήμερα, όλο και περισσότερες έρευνες προσπαθούν να προσδιορίσουν την οικονομική αξία της βιοποικιλότητας και να τεκμηριώσουν την ανάγκη, κατά το στάδιο του σχεδιασμού των πολιτικών για τη διατήρηση της βιοποικιλότητας, να λαμβάνονται υπόψη οι απόψεις και οι προτιμήσεις των πολιτών (Norton, 1986; Miller and McGee, 2001). Για το σκοπό αυτό πολλοί ερευνητές έχουν εφαρμόσει ψυχομετρικές έρευνες σε συνδυασμό με τη CVM (Spash, 2000; Kotchen and Reiling, 2000) με σκοπό τη διερεύνηση των κινήτρων απόδοσης οικονομικής αξίας στη θαλάσσια βιοποικιλότητα (López et al 2007). Σύμφωνα με αποτελέσματα ερευνών (Kellert and Berry 1980 Serpell 1986 Serpell 2004) έχει διαπιστωθεί ότι υπάρχουν δύο μεγάλες κατηγορίες κινήτρων α) το ενδιαφέρον, οι γνώσεις, η γενικότερη στάση απέναντι στα μη ανθρώπινα είδη των πολιτών για τα ζώα και β) η χρησιμότητά τους και τα οφέλη που πηγάζουν άμεσα ή έμμεσα από αυτά.

Στην παρούσα έρευνα γίνεται προσπάθεια να εκτιμηθεί η προθυμία πληρωμής των πολιτών για την προστασία της θαλάσσιας βιοποικιλότητας, με την ταυτόχρονη διερεύνηση των παραγόντων που επηρεάζουν τους πολίτες στο να καταβάλουν ένα χρηματικό ποσό για τη διατήρησή της. Ταυτόχρονα, για την καλύτερη διερεύνηση των κινήτρων απόδοσης αξίας στη θαλάσσια βιοποικιλότητα, χρησιμοποιήθηκε η κλίμακα

NEP (New Ecological Paradigm), η οποία χρησιμοποιείται για διερευνήσει τις αντιλήψεις, τις προθέσεις και τη στάση των πολιτών απέναντι στο φυσικό περιβάλλον.

Στη χώρα μας προηγούμενες εφαρμογές της CVM έχουν γίνει για την οικονομική αποτίμηση ειδών θαλάσσιας βιοποικιλότητας, τα οποία τελούν υπό εξαφάνιση. Οι Langford et al. (1998) χρησιμοποίησαν τη CVM για να εκτιμήσουν την WTP των πολιτών για την προστασία της μεσογειακής Φώκιας (*M. monachus*). Σύμφωνα με τα αποτελέσματα της έρευνας η μέση WTP ήταν ίση με 11.7 €, ενώ το εισόδημα, το φύλο, η ηλικία και το επίπεδο μόρφωσης των συμμετεχόντων στην έρευνα αποτέλεσαν τους προσδιοριστικούς παράγοντες της WTP. Άλλες εφαρμογές της CVM έγιναν από τους Langford et al. (2001) για την εκτίμηση επίσης της αξίας προστασίας της μεσογειακής φώκιας, τους Kaval et al. (2009) για την οικονομική αποτίμηση της χελώνας *Caretta caretta*, τους Matsiori et al. (2012) για την εκτίμηση της αξίας διατήρησης του αχινού *Paracentrotus lividus,* τους Matsiori et al. (2013) για την οικονομική αποτίμηση της μεσογειακής φώκιας. Οι Halkos and Jones (2011) διερεύνησαν, επίσης, την επίδραση των κοινωνικών παραγόντων στην απόφαση των ατόμων να πληρώσουν για την προστασία της βιοποικιλότητας. Παρόλα αυτά και από γνωρίζουν οι συγγραφείς, στη χώρα μας, δεν έχει αυτή αποτελεί την πρώτη προσπάθεια αποτίμησης της συνολικής αξίας διατήρησης της θαλάσσιας βιοποικιλότητας με ταυτόχρονη διερεύνηση των παραγόντων που ωθούν τους πολίτες στο να πληρώσουν για να αποφευχθεί η απώλειά της.

2. Υλικά και μέθοδοι

Για την υλοποίηση των στόχων της έρευνας διενεργήθηκε έρευνα με τη χρήση δομημένου ερωτηματολογίου, στα δημοτικά διαμερίσματα του Βόλου και της Θεσσαλονίκης και συλλέχθηκαν συνολικά 200 έγκυρα ερωτηματολόγια. Η έρευνα δομήθηκε σύμφωνα με τις αρχές των ερευνών της CVM και το δείγμα επιλέχθηκε με τυχαίο τρόπο με προσωπικές συνεντεύξεις και με τη βοήθεια ενός ερωτηματολογίου που κατασκευάστηκε και δοκιμάστηκε, για τις ανάγκες της έρευνας, σύμφωνα με τις οδηγίες της Υπηρεσίας Ωκεανών και Ατμόσφαιρας (NOAA panel) για τη βελτίωση της αξιοπιστίας των αποτελεσμάτων της (Arrow et al., 1993). Στο πλαίσιο της εφαρμογής της CVM δομήθηκε μια υποθετική αγορά με τη βοήθεια της οποίας οι συμμετέχοντες στην έρευνα εξέφραζαν την προθυμία πληρωμής τους για τη διατήρηση της θαλάσσιας βιοποικιλότητας.

Η δομή της υποθετικής αγοράς περιελάμβανε:

- Μια σύντομη περιγραφή των μέτρων που υποθετικά θα πρέπει να ληφθούν για την προστασία της θαλάσσιας βιοποικιλότητας, στο πλαίσιο ενός υποθετικού προγράμματος προστασίας της.
- Το μέσο και της συνθήκες πληρωμής, που απαιτεί η συμμετοχή των ερωτώμενων στο πρόγραμμα προστασίας της θαλάσσιας βιοποικιλότητας.
- Την ερώτηση απόσπασης της προθυμίας πληρωμής των ερωτώμενων. Στην παρούσα έρευνα η ερώτηση της επιθυμίας χρηματικής συνεισφοράς αποφασίστηκε να είναι διχοτομικής επιλογής (dichotomous choice). Πριν από την ερώτηση της διχοτομικής επιλογής προηγήθηκε μια ερώτηση που διερευνούσε την πρόθεση για συμμετοχή των ερωτώμενων σε ένα υποθετικό πρόγραμμα για την προστασία της θαλάσσιας βιοποικιλότητας, το οποίο θα λαμβάνονταν από την πολιτεία. Η συμμετοχή στο πρόγραμμα αυτό θα σήμαινε την καταβολή από αυτούς ενός χρηματικού ποσού.

Στο επόμενο στάδιο οι ερωτώμενοι είχαν αν επιλέξουν αν θα καταβάλλουν πραγματικά το χρηματικό ποσό που τυχαία επιλέχθηκε για τον καθένα, επιβεβαιώνοντας με αυτόν τον τρόπο τη συμμετοχή τους ή όχι στο πρόγραμμα. Τα ποσά της προθυμίας πληρωμής τυχαία μεταβάλλονταν μέσα στο δείγμα των συμμετεχόντων στην έρευνα και κυμαίνονταν από 1 έως 80 € (με βήμα 5€). Το ποσό αυτό καθορίστηκε από την προέρευνα, κατά την οποία οι συμμετέχοντες σε αυτήν είχαν τη δυνατότητα να εκφράσουν σε μια ανοιχτού τύπου ερώτηση, το μέγιστο ποσό που ήταν πρόθυμοι να καταβάλλουν για τη συμμετοχή τους στο πρόγραμμα. Η απουσία παρόμοιων ερευνών για τις περιοχές έρευνας οδήγησε στην ανάγκη καθορισμού του προτεινόμενου ποσού μέσα από την προέρευνα. Στη συνέχεια και για τα άτομα που δε δέχθηκαν να συμμετέχουν στο παραπάνω πρόγραμμα με την καταβολή ενός χρηματικού ποσού, στο ερωτηματολόγιο συμπεριλήφθηκε ερώτηση που σκοπό είχε τη διερεύνηση των λόγων που τους οδήγησε σε αυτή τη συμπεριφορά. Δεδομένου ότι η εξαρτημένη μεταβλητή δεν είναι ποσοτική αλλά διχοτόμος η ανάλυση των αποτελεσμάτων γίνεται με τη χρήση της λογιστικής παλινδρόμησης (logistic regression) (Bateman and Turner 1992). Με τη βοήθεια της λογιστικής παλινδρόμησης διερευνήθηκαν οι παράγοντες που επηρεάζουν του πολίτες στο να πληρώσουν για την προστασία της θαλάσσιας βιοποικιλότητας. Τέλος, η μέση προθυμία πληρωμής των ερωτώμενων για τη διατήρηση της βιοποικιλότητας υπολογίστηκε από τον παρακάτω τύπο (Hanemann 1989):

$$E(WTP) = \left(\frac{1}{\beta_1}\right) * \ln\left(1 + \exp^{\beta_o}\right)$$

Η οικολογική συνείδηση των ατόμων διερευνήθηκε με τη βοήθεια της του νέου οικολογικού παραδείγματος (NEP κλίμακα). Η κλίμακα NEP αποτελεί μια βελτιωμένη έκδοση μιας παλιότερης κλίμακας που χρησιμοποιήθηκε για τη διερεύνηση της οικολογικής συνείδησης των ατόμων (Dunlap and Van Liere 1978, Kotchen and Reiling 2000), η χρήση της οποίας έχει οδηγήσει σε αρκετά έγκυρα αποτελέσματα πρόβλεψης της συνείδησης των συμμετεχόντων σε αυτές τις έρευνας (Dunlap et al. 1992, Kotchen and Reiling 1999). Η κλίμακα NEP κατασκευάστηκε από τους Dunlap et al. (2000) και προσπαθεί να διερευνήσει τις στάσεις και αντιλήψεις των πολιτών με τη βοήθεια μιας πολυθεματικής ερώτησης 15 θεμάτων. Τα 15 θέματα ομαδοποιούνται στη βάση 5 παραγόντων: τα όρια ανάπτυξης, την ευθραυστότητα της ισορροπίας της φύσης, τον αντι-ανθρωποκεντρισμό, την εξαίρεση ή μη των ανθρώπων από τους περιορισμούς της φύσης και την πιθανότητα μιας οικολογικής καταστροφής. Στο πλαίσιο της παρούσας έρευνας και για την σκιαγράφηση της οικολογικής συνείδησης των συμμετεχόντων στην έρευνα, στα δεδομένα της NEP κλίμακας, εφαρμόστηκε Ανάλυση σε Κύριες Συνιστώσες (PCA) Η με τη βοήθεια της PCA εξήχθησαν οι παράγοντες που περιγράφουν τις αντιλήψεις των συμμετεχόντων για τη σχέση του ανθρώπου και της φύσης.

3, Δεδομένα και Μέθοδοι

3.1 Κοινωνικοοικονομικά χαρακτηριστικά συμμετεχόντων στην έρευνα

Στον Πίνακα 1 δίνονται τα κοινωνικοοικονομικά χαρακτηριστικά των συμμετεχόντων στην έρευνα.

Πίνακας 1: Κοινωνικοοικονομικά χαρακτηριστικά συμμετεχόντων στην έρευνα

	Μέσος όρος	**Τυπική απόκλιση**
Φύλο (%)	Γυναίκες (51%)	
Ηλικία (έτη)	35,67	14,46
Επίπεδο σπουδών (έτη)	Απόφοιτος ΑΕΙ (27,0%)	2,82
Οικογενειακή κατάσταση	Άγαμος/η (56,0%)	
Επαγγελματική δραστηριότητα	Ελεύθεροι επαγγελματίες (23,0 %)	
Αριθμός μελών οικογένειας	3,37	1,09
Μέσο μηναίο προσωπικό εισόδημα (€)	784,09	460,77
Μέσο μηνιαίο οικογενειακό εισόδημα (€)	1.681,17	756,23

3.2 Διερεύνηση αντιλήψεων πολιτών για τη σημασία της θαλάσσιας βιοποικιλότητας

Όπως αναφέρθηκε παραπάνω, η παρούσα έρευνα στοχεύει στη διερεύνηση της στάσης των πολιτών σε σχέση με τη θαλάσσια βιοποικιλότητα. Για το σκοπό στο ερωτηματολόγιο της έρευνας συμπεριλήφθηκαν ερωτήσεις που σκοπό είχαν τη εξαγωγή συμπερασμάτων για τη στάση των πολιτών σε σχέση με τον όρο θαλάσσια βιοποικιλότητα και το κατά πόσο οι πολίτες αναγνωρίζουν τη χρησιμότητα και τη σημασία της θαλάσσιας βιοποικιλότητας.

Σύμφωνα με τα αποτελέσματα της έρευνας, οι ερωτώμενοι, δηλώνουν ότι η χρησιμότητα της θαλάσσιας βιοποικιλότητας πηγάζει κυρίως από τη συμβολή της στην οικολογική ισορροπία και στην προσφορά τροφής (Πιν. 2). Η τιμή του a-Cronbach ήταν ίση με 0,856.

Πίνακας 2: Χρησιμότητα της θαλάσσιας βιοποικιλότητας

	ΝΑΙ	ΟΧΙ	Μη απαντήσεις
	(%)		
Προσφορά τροφής για τον άνθρωπο	42	47	11
Προσφορά προϊόντων στον άνθρωπο, όπως φάρμακα κ.λπ.	41	48	11
Προσφορά δραστηριοτήτων αναψυχής (παρατήρηση θαλάσσιας βιοποικιλότητας κ.λπ.)	37,5	50,5	12
Σημαντική πολιτισμική και πολιτιστική κληρονομιά	39,5	49	11,5
Συμβολή στη οικολογική ισορροπία	57	31,5	11,5
Πραγματική αξία (Ύπαρξη διαφόρων ειδών)	41,5	46,5	12
Συνδυασμός όλων λιγότερο ή περισσότερο	63	25,5	11,5

Από την άλλη πλευρά, οι ερωτώμενοι επισημαίνουν ότι η απώλεια της θαλάσσιας βιοποικιλότητας έχει σημαντικές συνέπειες τόσο για τον άνθρωπο όσο και για το φυσικό περιβάλλον. Οι απαντήσεις των ερωτώμενων, σε ανάλογη ερώτηση, αναδεικνύουν για μια ακόμα φορά τη σημασία που έχει η θαλάσσια βιοποικιλότητα για την οικολογική ισορροπία και την «υγεία» των θαλάσσιων οικοσυστημάτων (Πιν. 3). Ο έλεγχος αξιοπιστίας a-Cronbach της ερώτησης ήταν ίσος με 0,859. Ο συγκεκριμένος συντελεστής μπορεί να θεωρηθεί μέτρο συσχέτισης μεταξύ των δεδομένων προβλημάτων του δείγματος και οποιασδήποτε άλλης λίστας με ισάριθμα προβλήματα από πληθυσμό, που μετρούν τις επιπτώσεις της απώλεια της θαλάσσιας βιοποικιλότητας.

Πίνακας 3: Επιπτώσεις από την απώλεια της θαλάσσιας βιοποικιλότητας

	Σημασία απώλεια (%)				
	Καθόλου	Λίγο	Μέτρια	Πολύ	Πάρα πολύ
Μείωση των διαθέσιμων ιχθυοαποθεμάτων και της διαθέσιμης τροφής	1	2,5	17,5	32	47
Μείωση ωφελειών αναψυχής	3	8	27,5	29	32,5
Συνέπιες στην ανθρώπινη υγεία	0,5	4	16	31	47,5
Συνέπειες στην «υγεία» των θαλάσσιων οικοσυστημάτων – διαταραχή οικολογικής ισορροπίας	0,5	1,5	10	24,5	63,5
Αρνητικές συνέπειες στην ποιότητα ζωής των επόμενων γενεών	1	4	10,5	25	59
Απώλεια σημαντικών ειδών, με δικαιώματα ύπαρξης	2	1	10,5	26,5	60
Αρνητικές συνέπειες στην ποιότητα της ζωής μας στο μέλλον	1	3,5	9	26,5	60

Στη συνέχεια, οι συμμετέχοντες στην έρευνα ερωτήθηκαν κατά το πόσο αποδίδουν οικονομική αξία στη θαλάσσια βιοποικιλότητα Σύμφωνα με τις απαντήσεις τους η συντριπτική πλειοψηφία αυτών (96%) θεωρεί ότι η θαλάσσια βιοποικιλότητα έχει οικονομική αξίας. Στη συνέχεια αιτιολογώντας τους λόγους που τους οδηγούν στο να αποδώσουν οικονομική αξία στη θαλάσσια βιοποικιλότητα, διαπιστώνεται για μια ακόμα φορά ότι η συμβολή τους στην οικολογική ισορροπία είναι ο σημαντικότερος λόγος (Πιν. 4). Ο έλεγχος αξιοπιστίας a-Cronbach της ερώτησης ήταν ίσος με 0,937.

Πίνακας 4: Λόγοι που ωθούν στην απόδοση οικονομικής αξίας στη θαλάσσια βιοποικιλότητα

	ΝΑΙ	ΟΧΙ	Μη απαντήσεις
Παρέχει τροφή στον άνθρωπο	63	18	19
Συμβάλει στη φαρμακολογία	61	3	36
Συμβάλει στη βιομηχανία	52,5	3,5	44
Συμβάλει στον τουρισμό	57,5	3,5	39
Συμβάλει στην ισορροπία του οικοσυστήματος	72,5	3	24,5
Έχει αξία από την ύπαρξη της και μόνο	66	1,5	32,5

3.3 Αποτελέσματα εφαρμογής της κλίμακας NEP

Οι περιβαλλοντικές αντιλήψεις των συμμετεχόντων στην έρευνα σκιαγραφήθηκαν με τη χρήση της NEP κλίμακας. Η αναγνώριση των παραγόντων, οι οποίοι περιγράφουν την οικολογική συνείδηση των ερωτώμενων, έγινε με εφαρμογή Παραγοντικής Ανάλυσης με περιστροφή των παραγόντων με τη μέθοδο της ορθογωνικής περιστροφής (orthogonal rotation) ή μέθοδο της περιστροφής της μέγιστης διακύμανσης (Varimax). Τα αποτελέσματα μετά την περιστροφή των αξόνων δίνονται στον Πίνακα 5. Η ανάλυση σε κύριες συνιστώσες έδωσε 3 παράγοντες, που εξηγούν το 45,014 % της συνολικής μεταβλητικότητας. Για τον καθορισμό των παραγόντων που εξήχθησαν δε χρησιμοποιήθηκε το κριτήριο της ιδιοτιμής (eigenvalue), η λύση περισσότερων παραγόντων δε συνέβαλε ουσιαστικά στην αύξηση της εξηγούμενης διακύμανσης (Addams, 2000).

Πίνακας 4: Παράγοντες οικολογικής συνείδησης συμμετεχόντων στην έρευνα

Παράγοντες	**Ποσοστό Διακύμανσης**	**Χαρακτηριστική ρίζα**	**Cronbach's a**	**Total Cronbach's a**	**K.M.O.**	**Bartlett's Test of Sphericity**
Κυριαρχία ανθρώπου στη και φύση (F1)	19,513	2, 927	0,728	0,657	0,667	Approx. χ^2=581,770 df = 103 Sig. = .000
Άνθρωπος και περιβάλλον (F2)	15,199	2,280	0,623			
Ισορροπία – όρια φύσης (F3)	10,302	1,545	0,472			

3.4 Εκτίμηση της μέσης προθυμίας πληρωμής και διερεύνηση των παραγόντων που επηρεάζουν στην απόδοση οικονομικής αξίας στη θαλάσσια βιοποικιλότητα

Ο υπολογισμός της διάθεσης για πληρωμή των ερωτώμενων, όπως αναφέρθηκε και νωρίτερα, έγινε με την εκτίμηση ενός πρότυπου λογιστικής παλινδρόμησης με εξαρτημένη μεταβλητή την απάντηση των ερωτώμενων στην ερώτηση προθυμίας πληρωμής και ως ανεξάρτητες μεταβλητές τα κοινωνικοοικονομικά χαρακτηριστικά των συμμετεχόντων στην έρευνα και τα αποτελέσματα της εφαρμογής της κλίμακας NEP, τα οποία βοηθούν στην κατανόηση της οικολογικής συνείδησης του δείγματος. Ο τελικό μοντέλο περιελάμβανε μόνο τις προσδιοριστικές μεταβλητές που ήταν στατιστικά σημαντικές.

$$\mathrm{logit}[\Pr(Y=1)]=\beta_0 + \beta_1\,\mathrm{BID} + \beta_2\,F_1 + \beta_3\,F_3 + \beta_4\,\mathrm{FAM\_INC} + \beta_5\,\mathrm{EC\_BAL} + \varepsilon_i$$

Όπου Y είναι η διχοτομική εξαρτημένη μεταβλητή, η οποία έχει την τιμή 1 όταν οι ερωτώμενοι δέχονται να καταβάλουν ένα χρηματικό ποσό και 0 όταν αρνούνταν, BID είναι το χρηματικό ποσό που έπρεπε να δεχθεί να καταβάλει ο κάθε ερωτώμενος ή να απορρίψει, F_1 ο πρώτος παράγοντας που εξήχθη από την εφαρμογή της PCA στα δεδομένα της NEP κλίμακας και αναφέρεται στο «δικαίωμα» του ανθρώπου να κυριαρχεί στη φύση, F_3 ο τρίτος παράγοντας της PCA που αναφέρεται στην εύθραυστη ισορροπία της φύσης και τα όρια της, FAM_INC είναι το μέσο μηνιαίο οικογενειακό εισόδημα των ερωτώμενων και EC_BAL αποτελεί τη μεταβλητή που σκιαγραφεί την άποψη των ερωτώμενων για τη σημασία βιοποικιλότητας στη διατήρηση της ισορροπίας των οικοσυστημάτων.

Τέλος, η μέση WTP υπολογίστηκε στα 43,8€ με τη βοήθεια του τύπου (1). Όπως αναφέρθηκε παραπάνω, στο ερωτηματολόγιο συμπεριλήφθηκε ερώτηση που σκοπό είχε στο να διερευνηθούν τα αίτια της άρνησης των ερωτώμενων στο να καταβάλλουν ένα χρηματικό ποσό για τη διατήρηση της θαλάσσιας βιοποικιλότητας (Πιν. 6).

Πίνακας 5: Αποτελέσματα εφαρμογής του μοντέλου λογιστικής παλινδρόμησης

Μεταβλητές	Περιγραφή	b	Wald
Σταθερά		0,650 [0,013]	1,492
BID	Προθυμία πληρωμής	-0,07 [0.000]	28,591
F_1	Κυριαρχία ανθρώπου στη και φύση	-0,889 [0.004]	8,137
F_3	Ισορροπία – όρια φύσης	0,393 [0,097]	2,749
FAM_INC	Μέσο μηνιαίο οικογενειακό εισόδημα	0,001 [0,01]	6,691
EC_BAL	Συμβολή βιοποικιλότητας στην ισορροπία των οικοσυστημάτων	1,487 [0.021]	5,295
Nagelkerke R^2	0.579		
LR χ_{10}^2	96,671 [0.000]		
Hosmer-Lemeshow	11.543 [0.173]		
Mean WTP (€) 44.45			

Πίνακας 5: Λόγοι άρνησης καταβολής ενός χρηματικού ποσού για τη διατήρηση της θαλάσσιας βιοποικιλότητάς

	ΝΑΙ	ΟΧΙ
Δεν πιστεύω ότι μια τέτοια προσπάθεια θα λειτουργήσει	28,5	71,5
Δεν νομίζω ότι πρέπει να πληρώσω για την προστασία της περιοχής	22	78
Δεν πιστεύω ότι χρειαζόμαστε άλλους φόρους	26	74
Ήδη πληρώνω πολλά για την προστασία του περιβάλλοντος μέσα από άλλους τρόπους	21	79
Η κυβέρνηση θα πρέπει να αναζητήσει άλλα μέσα χρηματοδότησης ενός τέτοιου προγράμματος και να μη στηρίζεται στις δωρεές των πολιτών	37,5	62,5
Είναι δικαίωμά μου να απολαμβάνω τα οφέλη από προγράμματα προστασίας του περιβάλλοντος χωρίς να καταβάλλω κανένα χρηματικό ποσό	26	74
Αρνούμαι να αποτιμήσω το περιβάλλον σε χρηματικά ποσά	32	68
Αυτοί που χρησιμοποιούν πραγματικά την περιοχή οφείλουν να καταβάλλουν ένα χρηματικό ποσό και όχι εγώ	19	81
Δεν έχω αρκετές πληροφορίες για τον τρόπο εφαρμογής του προγράμματος για να καταβάλω ένα ποσό σε αυτό	29,5	70,5
Δεν πιστεύω ότι με αυτόν τον τρόπο θα προστατευτεί η περιοχή	32,5	67,5
Δε μου περισσεύουν χρήματα για αυτό το σκοπό	39	61
Τα χρήματα ξοδεύονται πολλές φορές για άλλους σκοπούς και όχι για το συγκεκριμένο	0,5	99,5
Είναι αρκετά αυτά που δώσαμε και δίνουμε στις τοπικές αυτοδιοικήσεις	0,5	99,5

Σύμφωνα με τα αποτελέσματα της έρευνας το μεγαλύτερο ποσοστό των συμμετεχόντων στην έρευνα δεν αρνείται να καταβάλει ένα χρηματικό ποσό γιατί δεν επιθυμεί αλλά γιατί δε διαθέτει την οικονομική ευχέρεια. Σημαντικά είναι επίσης και τα ποσοστά αυτών που δήλωσαν ότι ένα τέτοιο εγχείρημα αποτελεί ευθύνη της κυβέρνησης και όχι των πολιτών αλλά και αυτών που αντιτίθενται σε μια τέτοια προσπάθεια δηλώνοντας ότι δεν πιστεύουν ότι μπορεί να έχει αποτελέσματα.

4. Συμπεράσματα – Συζήτηση αποτελέσματων

Η παρούσα έρευνα στοχεύει στη διερεύνηση της σχέση μεταξύ της περιβαλλοντικής συνείδησης των πολιτών, των αντιλήψεών τους για τη θαλάσσια βιοποικιλότητα και των κοινωνικοοικονομικών τουw χαρακτηριστικών με την προθυμία πληρωμής τους για τη διατήρηση της θαλάσσιας βιοποικιλότητας. Για αυτό το λόγο αρχικά χρησιμοποιήθηκε η διεθνώς αναγνωρισμένη NEP κλίμακα, με τη βοήθεια της οποίας εξήχθησαν οι παράγοντες που περιγράφουν την οικολογική συνείδηση των πολιτών. Η εφαρμογή της PCA έδωσε 3 παράγοντες που αποτυπώνουν τη βασική διαφοροποίηση της στάσης των ανθρώπων απέναντι στο περιβάλλον. Ο πρώτος παράγοντας αναφέρεται στη δυνατότητα του ανθρώπου να κυριαρχεί με τις πράξεις του στο φυσικό περιβάλλον, αναγνωρίζοντας του έτσι εργαλειακή αξία.

Η χρησιμότητα του περιβάλλοντος πηγάζει από το γεγονός ότι μπορεί να ικανοποιεί τις ανάγκες του σε αγαθά και υπηρεσίες. Σε αυτή την κατηγορία συγκεντρώνονται οι πολίτες που εμφανίζουν περιβαλλοντικό ενδιαφέρον, το οποίο σχετίζεται άμεσα με ανθρωποκεντρικά κίνητρα και δείχνουν ενδιαφέρον για την υγεία του περιβάλλοντος κυρίως γιατί πιστεύουν ότι η καταστροφή του απειλεί ευημερία τους (Black et al., 1985; Hopper and Nielsen, 1991; Van et al., 1981). Ο δεύτερος παράγοντας αναφέρεται στη σχέση του ανθρώπου με τη φύση και «απορρίπτει» την ανθρωποκεντρική διάσταση του περιβαλλοντικού ενδιαφέροντος. Η βαθμιαία μεταβολή ενός τμήματος των πολιτών στην απόρριψη του ανθρωποκεντρισμού και στην αποδοχή της ίδιας αξίας του περιβάλλοντος αποτελεί συμπέρασμα πολλών ερευνών (Gardner and Stern, 1996). Ο προσανατολισμός προς οικο-κεντρικές αξίες σημαίνει ότι οι πολίτες ενδιαφέρονται για την προστασία του περιβάλλοντος ανιδιοτελώς.

Παρόλα αυτά, η ανάδειξη της διαφοροποίησης μεταξύ των δύο συμπεριφορών δεν είναι πάντα ευδιάκριτη (Stern and Dietz, 1994; Stern et al., 1995). Τέλος, ο τρίτος παράγοντας αναφέρεται στη λεπτή ισορροπία της φύσης και στα όρια που έχει στο να στηρίξει την ανθρώπινη δραστηριότητα. Σε αυτόν τον παράγοντα σκιαγραφείται η ανθρώπινη συμπεριφορά που βρίσκεται ανάμεσα στις δύο παραπάνω και δεν είναι διακριτό εύκολα αν το περιβαλλοντικό ενδιαφέρον πηγάζει από ίδιο ενδιαφέρον ή από ενδιαφέρον για τη φύση.

Στη συνέχεια, στο πλαίσιο της παρούσας έρευνας, οι παραπάνω παράγοντες μαζί με τα κοινωνικοοικονομικά χαρακτηριστικά των ερωτώμενων εισήχθησαν σε ένα μοντέλο λογιστικής παλινδρόμησης. Παρατηρώντας τον Πίνακα 5 γίνεται φανερό ότι όλες οι μεταβλητές έχουν τα αναμενόμενα πρόσημα. Τα άτομα που δηλώνουν ότι ο άνθρωπος έχει το δικαίωμα να κυριαρχεί στη φύση για να μπορέσει να καλύψει τις ανάγκες τους είναι λιγότερο πρόθυμα να καταβάλλουν ένα χρηματικό ποσό για τη διατήρηση της βιοποικιλότητας. Αντίθετα, τα άτομα που θεωρούν ότι η φύση έχει όρια και πολύ σύντομα μπορεί να ζήσουμε μια σημαντική οικολογική καταστροφή φαίνεται να είναι περισσότερο πρόθυμα στο να καταβάλλουν ένα χρηματικό ποσό για τη διατήρηση της βιοποικιλότητας.

Η περιβαλλοντική συμπεριφορά συνδέεται θετικά με την προθυμία πληρωμής των πολιτών για τη διατήρηση της βιοποικιλότητας (Kotchen and Reiling 2000). Το ίδιο συμβαίνει και με τα άτομα που θεωρούν ότι η συμβολή της βιοποικιλότητας στην ισορροπία των οικοσυστημάτων είναι σημαντική. Σύμφωνα με του Lopez et al (2007) η προθυμία πληρωμής των πολιτών για τη διατήρηση της βιοποικιλότητας επηρεάζεται τόσο από το πόσο είναι εξοικειωμένοι με το υπό εκτίμηση είδος όσο και από τις γνώσεις τους για τη σημασία τους. Θετική είναι επίσης, η σχέση μεταξύ του οικογενειακού εισοδήματος και της προθυμίας πληρωμής των συμμετεχόντων στην έρευνα, οδηγώντας στο συμπέρασμα ότι η διατήρηση της βιοποικιλότητας συμπεριφέρεται όπως ένα κανονικό αγαθό. Η θετική σχέση μεταξύ της προθυμίας πληρωμής και του εισοδήματος έχει επιβεβαιωθεί και σε άλλες έρευνες (Mohai, 1985 Guagnano et Al, 1995).

Τα αποτελέσματα της έρευνας δίνουν απαντήσεις για τη σχέση που υπάρχει μεταξύ της απόδοσης οικονομικής αξίας στη διατήρηση της θαλάσσιας βιοποικιλότητας και μπορούν να φανούν χρήσιμα στο πλαίσιο λήψης αποφάσεων για τη διατήρησή της αλλά και τον περιβαλλοντικό σχεδιασμό.

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Climate change, environmental effects of transport modes and transportation planning

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Abstract: The transport activity is at the origin of consumption of 1/3 of combustible fuels and of production of greenhouse gases at world level, of very serious sonor pollution effects in urban areas, of land occupancy and in some cases of landscape destruction. The paper addresses a quantification of effects of transport in all the aforementioned areas, both at world and national (Greek) level. As an efficient policy measure to counterbalance harmful environmental effects of transport has been suggested some form of internalization of external effects. An assessment of external costs of transport in monetary values is conducted for the various transport modes and various forms of internalization of external costs are discussed. It is also assessed whether targets set by international institution (like the Kyoto targets) can be reached through transport policy measures, by focusing on the more efficient and realistic ones.

Keywords: Environmental effects; Transportation planning; External costs; Internalization.

JEL Classification: H23; O44; R4; Q53.

1. Climate Change and human activity

Every human activity has a minor or major effect on the environment. Up to a certain level of industrial production, the environment may absorb the effects of human activities through a natural procedure. However, beyond this level, climate change may appear; this change is understood as a significant and lasting change in the statistical distribution of weather patterns over periods from some decades to centuries or even millions of years. The origins of climate change can be traced to human activities but also to factors exogenous to the human being, such as oceanic processes, solar radiation, plate tectonics, and volcanic activity. The question is whether at this point we have reached a level of human impact on the environment, beyond which climate change becomes irreversible.

The United Nations intergovernmental panel on climate change has concluded since the early 1990s that the balance of evidence suggests a discerned human influence on global climate. The analyses of authorities make clear that, (NASA, 2013):

– the average global temperature has risen between 1900 and 2000 by 0.7ºC and between 2000 and 2010 by 0.05ºC. If no change occurs in the actual rates of global warming, average temperatures will rise by 2.6÷4.7ºC in 2100,
– the global sea level has risen between 1880 and 2000 by around 20cm (1.66 mm/year) and between 2000 and 2013 by 4.8 cm, with an actual rate of increase of 3.16 mm/year. If no change occurs, a further rise at the global sea level of more than 30cm should be expected by 2100, due principally to the melting of polar ice caps,
– the volume of the arctic sea ice was reduced between 1980 and 2000 by 25% and

between 1980 and 2012 by around 40%,
- among 600 living beings tested, more than 75% present evidence compatible with an effort of adjustment to an increase in external temperature,
- known oil reserves will be exhausted at the latest by 2050÷2060,
- there will be major shifts in the world's vegetation zones, deserts will become hotter and desertification will increase.

One of the main transport characteristics of the period from the 1950s up to now is an increase in the mobility of the population. There has been a significant increase in the amount of trips, mainly due to population growth and to the improvement of the standard of living, which were accompanied by an increase in the car ownership index.

The increase of human and freight mobility could not have been achieved without environmental implications. However, these repercussions could have been minimized, if in the early stages the necessity had been realized that the transport system (in regard to its infrastructure, as well as its operation) should be developed in a rational manner, provided that the properly developed various transport infrastructure networks and transport systems would cooperate efficiently in order to serve any emerging demand. They should compete on equal terms and would be organized in an environment-friendly way, thus securing better environmental conditions, lower energy consumption and less accidents and congestion, (Tricker, 2007).

2. Air pollution and transport

Trends in energy-related CO_2 emissions continue to be bound closely to those of the global economy, (Fig. 1), with the few declines observed in the last decades being associated with events such as the oil price crises, terrorism attacks and the recent global recession. Transport is an important air pollution emitter, accounting for 90÷95% of carbon monoxide (CO) emissions, 60÷70% of nitrogen oxides (NO_x), 40÷50% of hydrocarbons (HC) and volatile organic compounds (VOC), 30% of carbon dioxide (CO_2) emissions, 5% of sulfur dioxide (SO_2) and 25% of suspended materials, (IEA/UIC, 2013). Table 1 presents the emissions of some air pollutants provoked by the various transport modes for passenger and freight transport.

In 2010, the transport sector was responsible for the 27 EU countries for a 30.9% of total CO_2 emissions, the other sectors contributing electricity and heat 38.4%, the manufacturing sector 13.2%, the residential sector 11.2%, the agriculture sector 1.4% and the other sectors 4.9%, (EU, 2013). Within the transport sector, contribution of the various transport modes in CO_2 emissions was for the 27 EU countries for the year 2010 as follows: roads 71.7%, navigation 14.6%, aviation 12.3%, railways 0.6%, other (non-specified) 0.8%, (EU, 2013). However, changes between 1990 and 2010 in CO_2 emissions from fuel combustion for the various transport modes are illustrated for the 27 EU countries in Fig. 2, whereas the comparative CO_2 emissions of the various transport modes are given for the 27 EU countries in Fig. 3.

As a way to confront the greenhouse effect and CO_2 emissions, a carbon tax of 20.0 US dollars per ton of carbon emitted has been suggested. If this internalisation proceeds, something that is not very likely, a shift of traffic to the railways can be expected. Assessment of this shift of traffic may be approached as follows, (Van Dender, 2013; Profillidis, 2014).

First a decision should be made whether:
- internalisation shall include only CO_2 emissions or all external costs,
- internalisation shall be based on medium external cost or marginal social cost.

Figure 1: *Annual growth of global GDP and per capita CO_2 emissions*

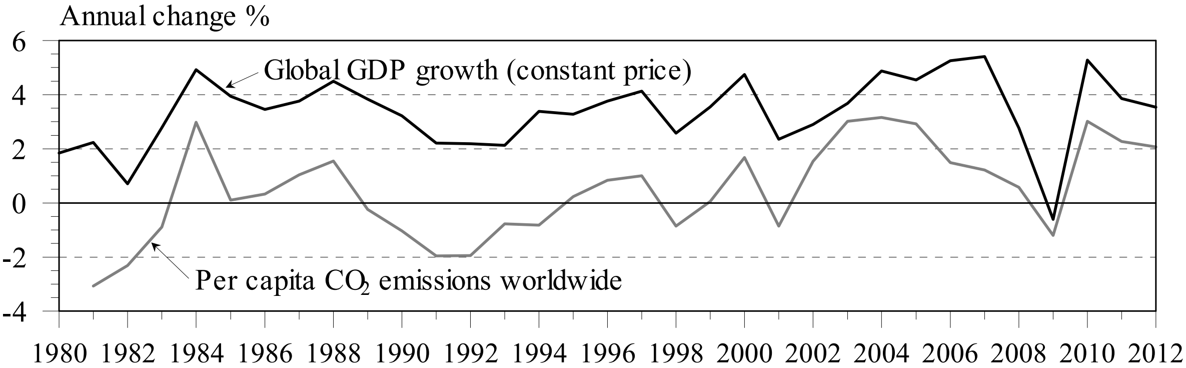
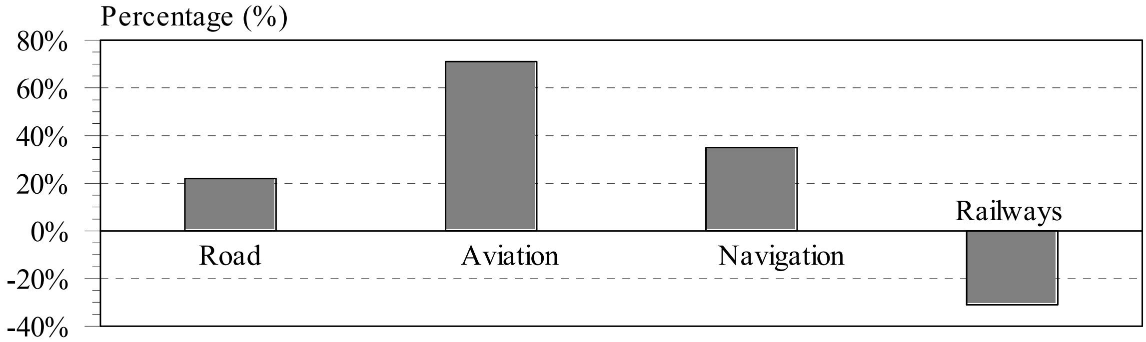


Table 1: *Emissions of pollutants provoked by various transport modes (Profillidis, 2014)*

Pollutant	Passenger transport					Freight transport		
	Unit	Rail	Catalytic car	Airplane	Bus	Unit	Rail	Truck
CO_2 emissions	gr/p-km	60	120	300	60	gr/t-km	50	220
CO emissions	gr/p-km	0.05	1.3	8.1	0.15	gr/t-km	0.07	1.58
NO_x emissions	gr/p-km	0.08	0.34	6.4	0.2	gr/t-km	0.16	3.18
Hydrocarbons	gr/p-km	0.02	0.15	1.4	0.08	gr/t-km	n.a.	n.a.

Figure 2: *Changes in CO_2 emissions from fuel combustion by the various transport modes*
for the 27 EU countries between 1990 and 2010, (IEA/UIC, 2013)



3. Energy consumption

For the 27 EU countries in the year 2011, the transport sector consumed 33.0% of total energy (41.0% in Greece), households 24.7% (28.7% in Greece), industry 26.0% (17.6% in Greece), agriculture 2.2% (1.6% in Greece), services and other activities 14.1% (11.1% in Greece), (EU 2013). Percentages of the consumption of energy at the world level were for the year 2010 as follows: transport 27.3%, industry 27.8%, domestic and tertiary sector 36.0%. World energy demand was satisfied in 2006 from five main sources: oil 37.8%, gas 23.8%, coal 25.6%, nuclear 8.1%, hydroelectric 6.1%, alternative 0.9%. While a global oil shortage should be expected around 2050÷2060, known gas reserves will continue to serve the planet and satisfy world demand without excessive prices at least until 2100÷2150.

Within the transport sector for the 27 EU countries in the year 2012, railways consumed 1.2% of total energy for transport activities, road transport 73.3%, navigation and pipelines 10.0%, and air transport 13.4%, (IEA/UIC, 2013). Fig. 3 illustrates the evolution of energy consumption by transport mode from 1990 to 2012 for the 27 EU countries, whereas Fig. 4 illustrates specific energy consumption per unit transported (passenger-km, ton-km).

Figure 3: *Energy consumption of the various transport modes for the 27 EU countries (EU, 2013)*

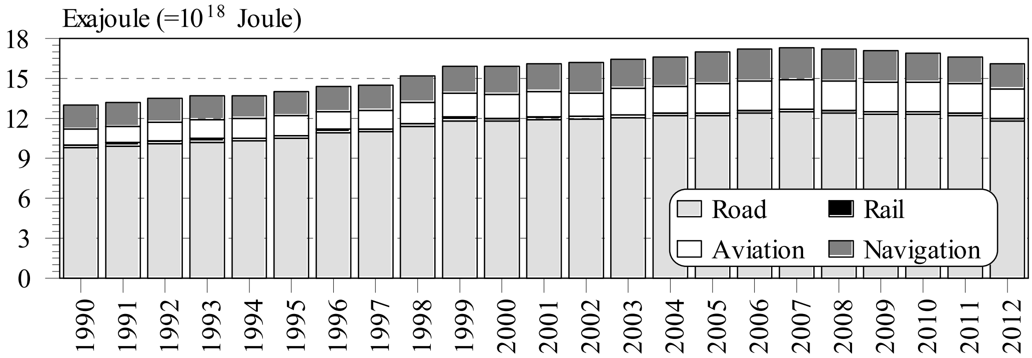
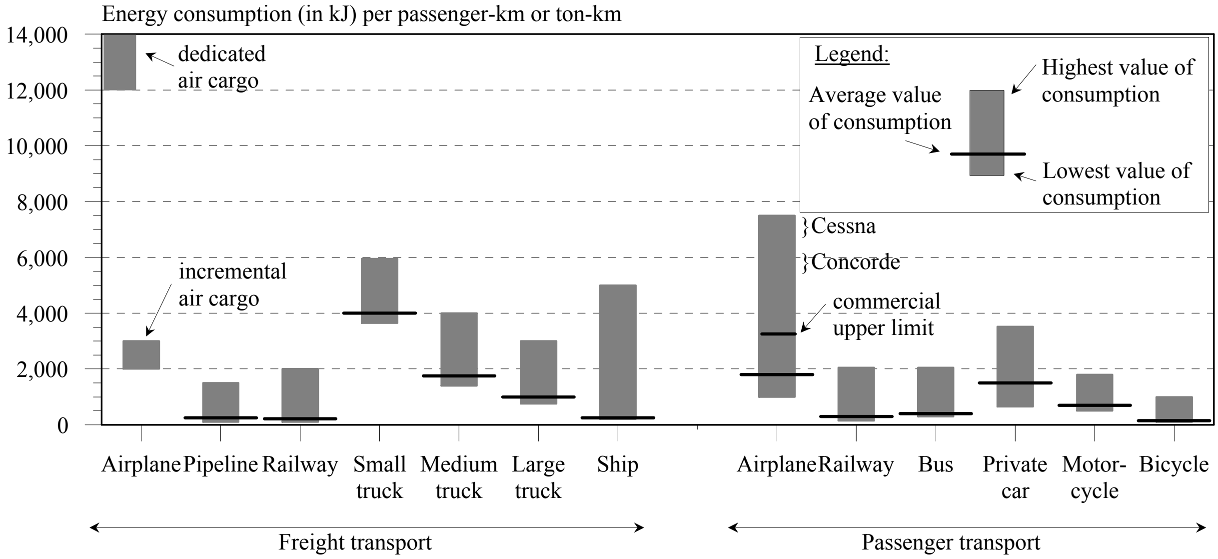


Figure 4: *Specific energy consumption of railways and other transport modes, (Profillidis, 2014)*



4. Noise exposure and transport activity

Today, about 44.3% of the residents of the 27 countries of the European Union plus Norway and Switzerland were exposed to noise levels exceeding 55 dB(A), a level that although officially tolerable (noise becomes annoying for humans when exceeds the limit of 55÷65 dB(A), (Moliner *et al*., 2013)), is yet unpleasant and undesirable, (Fig. 5). These noises were produced to 35.8% by road transports and to 5.4% and 3.1% by railways and airplanes respectively. The situation is dramatic in urban agglomerations were 11% of the population are exposed to a noise level of 70 dB. It has been estimated that for the EU countries the willingness to pay, per person disturbed by noise in order to avoid noise exposure, has been increased by almost 0.11% of per capita income per unit of dB(A) when noise level exceed the tolerable value of 55 dB(A).

5. Land occupancy, landscape

Transport infrastructure occupies space that can have other uses in urban and non-urban areas. Awareness of this effect is more apparent in densely populated countries, such as Japan, the Netherlands, Belgium, etc., (Fig. 6). If the carrying capacity of all transport modes is compared to their land occupancy, then railways have a clear advantage, since the space required by a private car passenger is 22 times compared to rail, and by a bus passenger 1.7 times compared to rail, (Profillidis, 2014).

Figure 5: *Percentage population in urban areas (with a population in excess of 250,000 inhabitants) of 27 EU countries + Norway exposed to different noise levels (in dB(A)) that comes from various transport modes*

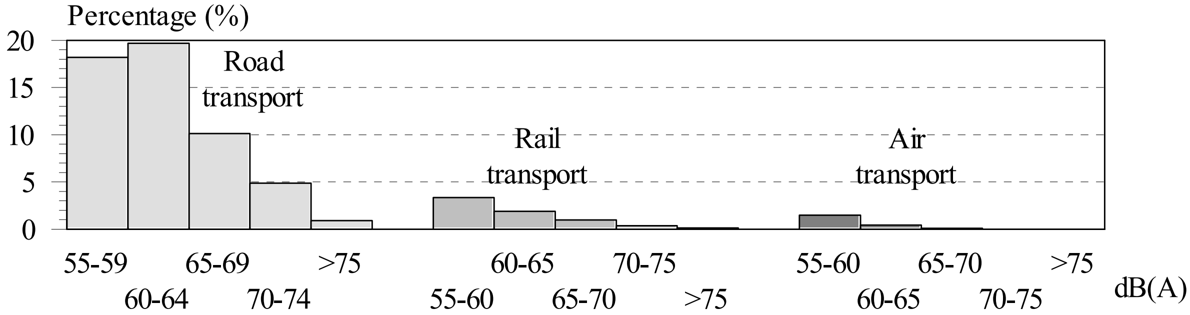
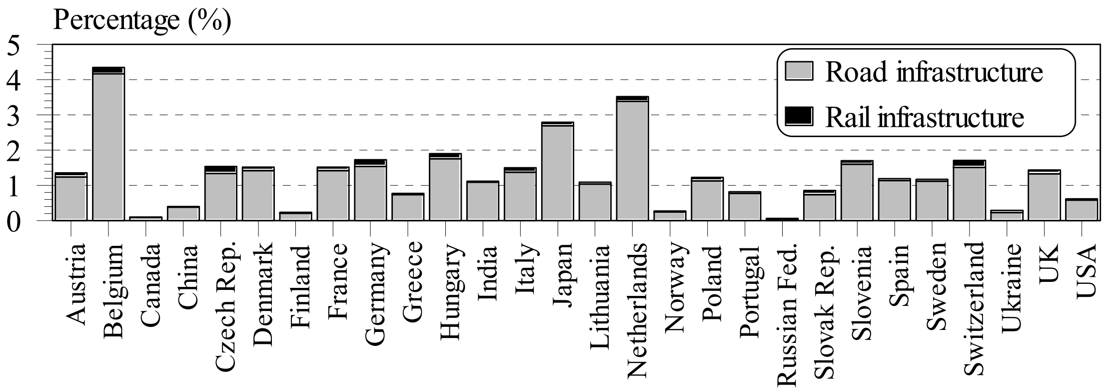


Figure 6: *Land occupancy (as percentage of land area of each country) of road and rail infrastructure for various countries of European Union and worldwide*



6 Transport policies and impact on safety and environment

Traffic accidents, air pollution and noise are closely linked to common factors, such as: traffic flow, traffic speed, power of vehicles and the composition of traffic. The policies, which aim to prevent accidents, air pollution and noise are based on the same principles: travel demand management, improving both of safety and environmental performance of vehicles, strengthening, encouraging and promoting the use of modes that perform better as far as the safety and environmental protection is concerned, (such is railways, public transport modes, etc.), (Chapman, 2007; Proost and Van Dender, 2012).

However, it is not ensured that a measure taken to improve traffic safety will automatically have the same possible impact on the environment and vice-versa. Some examples of this conflict are:

- the use of electric or hybrid vehicles will prove beneficial as far as the reduction of air and noise pollution and the fuel consumption is concerned, but the silence of an electric engine will increase the risk of safety of pedestrians and bicyclists, as they may not be aware of the moving vehicle until it is too late,

- the construction of noise barriers will reduce the noise level of the surrounding areas but could have a negative impact if the visibility of the drivers or the pedestrian is affected, etc.

To reduce both pollution and the number of accidents, it is possible to act on the following elements: road vehicles, transport planning, road infrastructure and traffic management. Table 2 illustrates a synthesis of the possible safety and environmental related conflicts and convergences of various policies and Table 3 (next page) illustrates the impact of transport policies on economic and urban development, health, environment protection and energy.

Table 2: *Possible conflicts and convergence between safety and environmental policies, (Profillidis and Botzoris, 2010)*

		Energy conservation	CO_2 reduction	Air quality	Noise reduction	Landscape
Road vehicles	Vehicle weight reduction	+	+	×	?	×
	Power reduction	+	+	+	?	×
	Limiting maximum speed	+	+	+	+	×
	Electrified vehicle	?	+/–	+	+	×
	Vehicle check	+	+	+	+	×
	Driver training	+	+	+	+	×
Transport policy	Transfer to rail	+	+	+	+	+/–
	Strengthening public transport	+	+	+	+	×
Road infrastructure	By-passes	+/–	+/–	+	+/–	–
	Noise barriers	×	×	+	+	–
Traffic	Reduction in speed limits	+	+	+	+	×
	Traffic calming	+/–	+/–	×/+	+	+
	Congestion management	+	+	+	–	×

\+ positive effect × no effect – negative effect +/– effect may be either way ? uncertain effect

7. External cost of transport

7.1. Definition of externalities and quantification of external cost

For many decades, a crucial issue concerning the various components of external effects was their accurate and objective quantification in monetary values. This work has been conducted and applied to data of the year 2008, and refers to the 25 EU countries (Malta and Cyprus do not have railways) plus Norway and Switzerland, (Van Essen *et al*., 2011). The various components of external costs under study are: accidents, noise, air pollution, climate change, nature and landscape, additional costs in urban areas, up- and down- stream processes. Congestion costs are usually presented separately.

Total external costs (excluding congestion costs) amount for the year 2008 to more than 500 billion €, which is 4.0% of the GDP of the 27 countries taken into account (25 EU countries + Norway + Switzerland). Climate change is the most important cost category, with 29% of the total costs. Air pollution amounts to 10.4% and accident costs amount to 43% of the total costs. The costs of noise and up- and down- stream processes amount to 9.6% of total costs. The costs for nature, landscape and undesired urban effects amount to 1.0% of total costs, (Fig. 7), (Van Essen *et al*., 2011).

Table 3: *Transport policies and impact on economic and urban development, health, environment protection and energy, (Figueroa and Ribeiro, 2013)*

System goal	Category related to sustainable transport goals	Example of indicative approach for assessing progress	Reduce Need to Use Car and Expand Mobility Options and Services: Promote compact, transit oriented, mixed land use development	Build-upgrade non-motorized transport infrastructure	Adopt pricing policies over car ownership, distance based tariff	Adopt strict parking regulation and pricing	Promote and upgrade public transport options	Innovate and expand mobility services	Use of Information Technology Systems (ITS)	Improve Vehicles: Adopt efficiency and emission reduction standards for conventional technology vehicles	Incentives supporting research and development	Promote - Uptake Alternative fuels: Adopt standards (e.g. low carbon fuel, renewable fuel)	Incentives to increase advance electric drive technology vehicles	Information campaigns - Promotions campaigns and artnerships
Economic Development	Functionality and Efficiency	Reduced travel time, travel cost and trip uncertainty	Essential	Essential	Limited	Limited	Essential	Essential	Essential	Uncertain	Limited	Uncertain	Uncertain	Limited
	Operation	Quality of system condition. Percent of lane-kms by pavement conditions.Infrastructure maintenance expenses.	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Limited	Limited	Limited	Limited	Limited
	Support General Economy	Cost/benefit new facilities. Indirect jobs supported (created). Lost time due to congestion	Limited	Essential	Essential	Essential	Essential	Essential	Limited	Limited	Essential	Limited	Limited	Limited
Urban Development and Equity	Accessibility	Ease of reaching opportunities. Reduced access time from origin to destination.Good conditions for biking-walking	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Uncertain	Uncertain	Uncertain	Uncertain	Uncertain
	Affordability	Passenger trips per household. % of income used to pay for transport services (<20%)	Essential	Essential	Uncertain	Uncertain	Essential	Essential	Essential	Limited	Limited	Limited	Essential	Limited
	Acceptability	Public acceptability. Participation in decision-making progress	Limited	Limited	Uncertain	Uncertain	Essential	Limited	Limited	Uncertain	Uncertain	Uncertain	Essential	Essential
Health and Environment Protection	Traffic Safety	Reduction of road traffic deaths and injuries	Limited	Essential	Essential	Limited	Limited	Limited	Limited	Uncertain	Limited	Uncertain	Uncertain	Limited
	Universal Access	Access provided for the elderly, very young and people wit disabilities	Essential	Essential	Uncertain	Uncertain	Essential	Essential	Essential	Uncertain	Essential	Uncertain	Limited	Limited
	Physical Activity	Public health benefits from increased physical activity	Essential	Essential	Limited	Limited	Limited	Limited	Limited	Uncertain	Uncertain	Uncertain	Uncertain	Uncertain
	Air Pollution	Air pollution level reduction	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Limited	Essential	Limited
	Noise	Noise level reduction	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Limited	Limited	Limited	Limited	Limited
	Ecosystem Impacts	Land use area - Sprawl: % suburban dwelling - Biodiversity protection	Essential	Limited	Limited	Limited	Limited	Limited	Limited	Uncertain	Uncertain	Uncertain	Uncertain	Limited
GHG	Green House Gas emissions	Green House Gas emissions reduction	Essential	Essential	Essential	Essential	Essential	Essential	Limited	Essential	Essential	Limited	Limited	Essential
Energy security	Diversification of Energy Sources	Alternative fuel consumption per vehicle and passenger km	Essential	Essential	Limited	Limited	Essential	Essential	Essential	Uncertain	Limited	Essential	Essential	Essential
	Resilience	Sector is secure from, ready for and resilient to threats and hazards	Essential	Essential	Limited	Limited	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential
	Independence from Fossil Fuels	Percentage reduction in use of fossil fuels	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential

Essential: academic agreement, positive examples of implementation

Uncertain: academic dissent, of lack of substantive evidence

Limited / potential opposite: academic agreement and evidence of limited or opposite effect

Road transport is the mode with the highest share (93%) in total external costs, followed by air transport (5%). It should be stressed that in the calculation of external costs of air transport, only flights within EU have been taken into account, something that explains the low share (5%) of air transport in total external costs. On the contrary, railways have a small share (less than 2%) in total external costs and waterways even smaller (0.3%). Two thirds of external costs are caused by passenger transport and one third by freight transport, (Van Essen *et al.*, 2011).

Fig. 8 illustrates average external costs for passenger and freight transport for the 25 EU countries + Norway + Switzerland. The various aspects of transport offer, such as load factor, vehicle stock, population densities, share of diesel and electric train traction and other, have been taken into account.

Figure 7: *Average external costs for passenger and freight transport for the various transport modes, (25 EU countries+Norway+Switzerland), (Van Essen et al., 2011)*

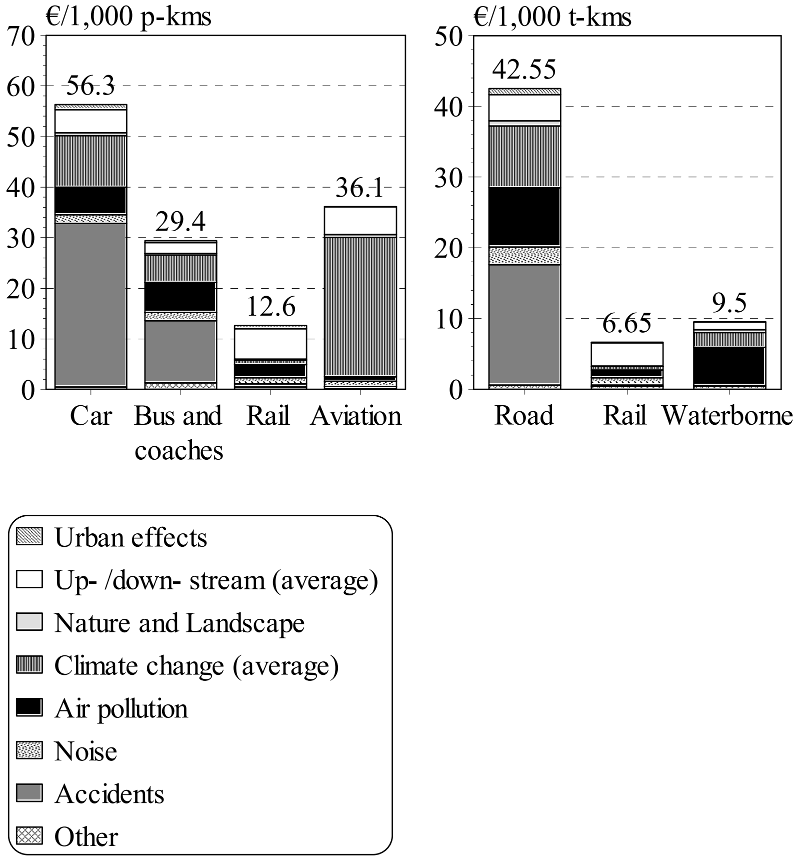
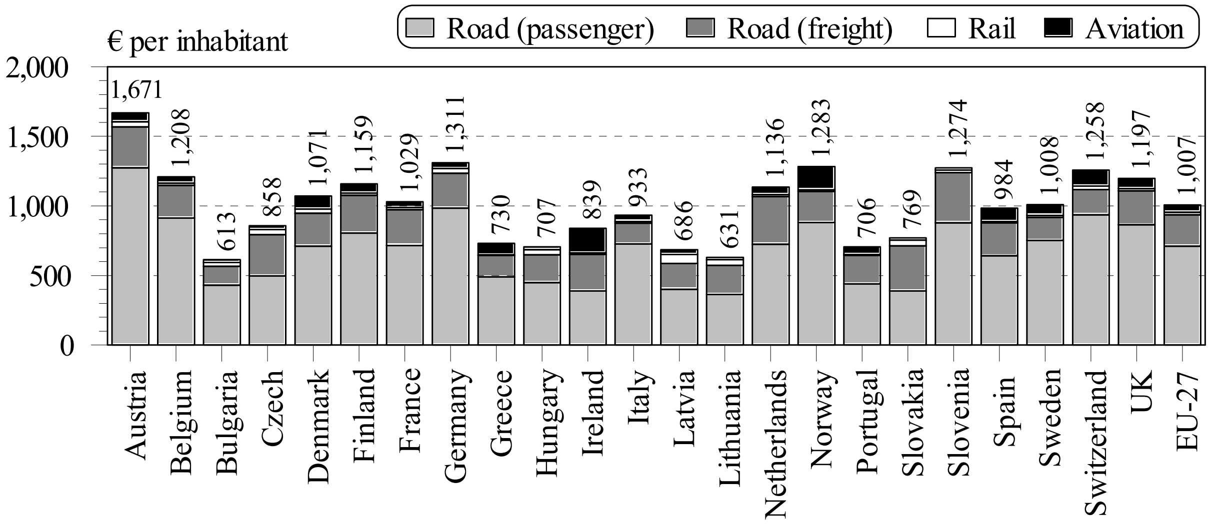


Figure 8: *External costs per inhabitant and transport mode and year for various EU-27 countries (excluding congestion)*



7.2 Internalisation of external cost and impact on transportation planning

Many efforts to internalize (that is to ask each transport mode to pay the external costs it causes) external costs have failed to establish the appropriate legislation instruments. In order to internalize the external costs properly, the following action strategies are appropriate, (Crozet, 2004; Macharis *et al.*, 2010):

– application of road pricing schemes for passenger cars (i.e. by mean of tolls), especially in urban areas, in order to confront capacity problems. A differentiation of charges could be applied, depending upon the net weight and the power of cars as well as the emission of pollutants,
– introduction of road pricing schemes for freight vehicles. The applied charges must consider both accident cost and environmental costs, like air pollution, noise, etc.,
– introduction of a fuel price scheme for all transport modes, which takes into account the external costs of each transport mode. The inclusion in this measure of international air transport is necessary in order to avoid tax distortions among transport modes.

A priority must be given to the internalisation of external costs caused by road and air transport, because these sectors of transport process are responsible for a huge amount of the total external costs. A study on the internalisation of external costs for the 27 EU countries was based on the increase of operation costs that will result and on cross-elasticities between rail and other transport modes. If internalisation is conducted according to medium external costs, expected shift of traffic to the railways would be on the order of 12÷15% for passenger and up to 24% for freight. If, however, internalisation is conducted according to the marginal social cost, the expected shift of traffic for passenger and freight would be on the order of only 6%, (Profillidis and Botzoris, 2010).

Table 4 illustrates an assessment of the effects of the internalisation of external costs and harmonization of infrastructure user charges to the market prices of various transport modes. We can conclude that, (Verhoef, 1994; Crozet, 2004; Macharis *et al.*, 2010; Van Dender, 2013):

♦ the internalisation of average external cost would change tariffs of rail and road transport. In passenger transport the effect would vary between 20÷30% in favour of railways whereas in freight transport the effect would be even more significant (40%),

- charging of infrastructure for rail, road and airport on equal basis and eventual internalisation of external costs may change current terms of competition. If infrastructure expenses are covered from charges paid by rail operators, this will be detrimental for railways. If all external costs are internalized, with airports having far higher external costs compared to rail and road services, this will be detrimental for air transport,
- the harmonization of infrastructure charges would have significant effects on cost structure of rail freight transport and on waterway transport which pays today no infrastructure charges.

Table 4: *Potential effects on transport prices due to internalisation of external costs and to harmonization of infrastructure user charges, (Crozet 2004)*

Measure	Road	Railway	Air	Inland waterway
Internalisation of average external cost	Passenger: 36%÷43% Freight: 70%÷80%	Passenger: 5%÷25% Freight: 30%÷40%	Passenger: 9%÷30%	Freight: 90%
Internalisation of marginal external cost	Passenger: 14%÷15% Freight: 25%	Passenger: 3%÷10% Freight: 15%	Passenger: 30%÷60%	Freight: 10%
Harmonization of infrastructure user charges	Passenger: 5%÷7% Freight: 6%÷10%	Passenger: 0%÷7% Freight: 36%÷55%	Passenger: 0%	Freight: 117%
Coverage of infrastructure and external costs (gap between total costs and accountable revenues)	Passenger: 30% Freight: 50%÷80%	Passenger: 20%÷50% Freight: 90%÷140%	Passenger: 22%÷44%	Freight: 190%

8. Conclusions

Emergency to stop CO_2 emissions and the resulting climate change push to the adoption of efficient measures, among them in transport sector. In the present paper it is discussed and quantified the effect of an eventual internalization of external costs in the transport sector, and in particular the expected shift of traffic and the increase in transport costs. Policy measures towards a more rational energy consumption, reduction of noise and environmentally friendly land occupancy are also suggested.

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Sustainable transportation planning and traffic noise reduction in urban built environment

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Abstract
This research examines the relationship between transportation planning, sustainable transport modes such as walking and bicycling and urban traffic noise. High level of traffic noise could decrease the real estate value and discourage citizens to walk or bike. This research will explain how traffic noise affects sustainable transportation in the city of Volos, which is a medium scale Greek city. During this survey an amount of 230 questionnaires were completed through personal interviews. The participants were categorized according to their sex, age, level of education, profession and financial income. They answered a questionnaire containing 18 questions about choosing walking or bicycling for their daily urban trips and route selection according to the perceived traffic noise. Furthermore, they proposed actions focusing to reduce the traffic noise in the city and the taxation they could afford in order to implement relative projects. This research concluded that traffic noise affects citizens' route selection and decision to walk or bike in the framework of sustainable transportation planning. Furthermore, citizens are willing to pay an annual tax for relative projects despite their income depression. Finally, authors resulted that promotion of sustainable transportation and reduction of traffic noise could improve quality of living in urban areas, especially in the era of economic crisis.

Keywords: Sustainable, Transportation, Traffic noise, Urban, Built environment
JEL Classification: R4, R41, Z1, Z18

1. INTRODUCTION

Traffic noise is an important environmental health issue affecting public health and wellbeing of people exposed. The objective of this research is to examine the relationship between transportation planning, sustainable transport modes and urban traffic noise. Active living in terms of urban transportation relates to sustainable transport modes such as walking and bicycling. The conduction of the research through personal interviews has taken place in the city of Volos, which is a typical medium scale city of Greece. This study focuses on the affection of traffic noise on citizens' choice to walk or bike for daily urban trips and their route selection. Furthermore, aims to recognize and face the problem of traffic noise proposing remedial actions and investigating citizens' willingness to pay for relative projects.

Noise in big cities is considered by the World Health Organization to be the third most hazardous type of pollution, following air and water pollution (2005). Concerns about health impacts and annoyance caused by environmental noise are growing among both the general public and policy makers in Europe. Extensive urbanization and increase of road transport define the main driving forces for the environmental noise exposure of the population (Vogiatzis, 2011). According to World Health Organization, 33% of the individuals are annoyed during the daytime and 20% have disturbed sleep at night because of traffic noise (2011). The European Environmental Agency estimated that an amount between 20% and 40% of the population, about 100-200 million, was exposed to noise levels leading to serious annoyance, speech interference and sleep disturbance. European Union adopted the directive 2002/49/EC relative to the evaluation of ambient outdoor environmental noise. Surveillance of ambient community noise is now mandatory for European cities with population over 250,000. As a result, several cities have established noise surveillance programs and set goals to reduce the size of the population exposed to high noise levels. Reducing noise at the source will require new road standards and lower engine noise levels. Noise abatement programs have an environmental justice dimension and need to target the at-risk population (Moudon, 2009).

Traffic related noise is becoming the most health-threatening environmental stressors in Europe, and more people are exposed to traffic-related noise than to any other environmental stressors. Excessive exposure to noise could be considered as a health risk in a way that noise may contribute to the development and aggravation of stress related conditions such as high blood pressure, coronary disease, ulcers and migraine headaches.

In recent years has been recognized the importance of urban form on sustainable development. Urban land-use pattern and urban geometry are two basic characteristics of urban form. They fundamentally determine transportation demands, which directly affect traffic noise and air pollution. Some researchers have studied the spatial relationship among urban form, traffic volume and traffic noise (Geerlings *et al.*, 2003). Other researchers have investigated the influences of existing urban forms on vehicle transport and pedestrian exposure to traffic noise (Sheng *et al.*, 2011). Furthermore, researchers have used the Geographic Information System as a tool in spatial analysis and modelling in order to estimate the level of noise in urban areas (Moragues *et al.*, 1996).

Motorized transportation is mainly responsible for urban traffic noise. Mopeds, scooters and motorbikes are in large use in the Southern European countries of Spain, Italy and Greece. In these countries the possibility of driving for a large part of the year under good climate conditions, together with the need to overcome the problem of city traffic congestion, makes the use of power two vehicles (PTW) extremely attractive. PTW produce additional traffic noise which is especially annoying to citizens directly exposed to noise as in the case of pedestrians and bicyclists. The percentage of annoyed individuals by PTW is about 16% lower than those annoyed by the PTW and cars all together, although the PTW noise is the most relevant in terms of L_{Aeq} (Paviotti *et al.*, 2012).

Railway public transport modes such as Metro and Tramway are very important for the reduction of traffic congestion. They are considered to be sustainable means of transportation, due to the substantial reduction of air pollutant emissions by decreasing the number of cars, PTW and heavy vehicles (buses) in the urban road network. However, an important adverse effect of their operation is the increased level of ground-borne vibration and air-borne noise (Vogiatzis, 2012).

The need for studies regarding the noise pollution and its consequences for the community has motivated various researchers on this problem in several countries. A survey in the city of Kerman revealed that 70% of the participants classified the noise of their street as "very high" and 86% answered that noise produce physical and psychological annoyance to them (Mohammadi, 2009). A survey in the city of Curitiba revealed that the main isolated noise sources disturbing citizens were traffic (73%) and neighbours (38%), (Zannin *et al.*, 2003). In main roads of the city of Messina the daily average sound levels due to road traffic exceeded environmental standards by about 10dBA resulting to a 25% of the resident population highly disturbed by road traffic noise. Environmental noise exhibits a certain degree of spatial variance resulting primarily from the peculiar geo-morphological structure of the town and from the transport infrastructure (Piccolo *et al.*, 2005).

Walking and bicycling are considered to be sustainable means of transportation due to the environmental benefits and raise of public physical activity. Implementation of audit tools for pedestrian built environment could change the balance in favour of sustainable transportation (Galanis *et al.*, 2012).

2. METHODOLOGY

2.1. Study Area

This research examines the relationship between sustainable transport modes and urban traffic noise in the city of Volos, Greece. Volos is a typical medium sized city with a population of 145,000 citizens, a passenger and freight port and an industrial area. Traffic congestion is present during daily rush hours or bad weather conditions (rain, snow). The city has a wide but not completely operational bikeway network inhibiting bicyclists to safely access desired destination points. Furthermore, the pedestrian built environment could be characterized of a medium walkability level due to lack of proper walking facilities, especially in neighbourhoods.

2.2. Data Collection

In order to attend the objectives of this research the authors have developed a questionnaire which main objectives are:

- Identify if traffic noise affects the transport mode selection.
- Identify if traffic noise affects the route selection.
- Identify if citizens are aware of the negative impacts of traffic noise.
- Identify if citizens are willing to pay for traffic noise reduction projects.

The questionnaire was formed of 18 questions, 5 of them referred to the participants' demographic data of age, sex, education level, profession and income. A total amount of 230 questionnaires were processed. A group of 230 questionnaires were processed from two researchers through personal interviews to familiar persons and citizens randomly picked up, walking across main urban streets and pedestrian zones. Twice as many citizens were asked to participate but many refused and some of them stopped the interview for personal reasons or to answer a phone call without finishing it. Those interviews were not taken part in our sample. The duration of each interview was not longer than 10min. Citizens were willing to participate in the research but did not have time to answer the questions or were not familiar with personal interviews.

One important conclusion of this process was that young people despite their high education level are either not familiar with research projects or consider their opinion meaningless to the city authorities.

3. Results

3.1. Demographic Characteristics

Among the responders, 58.3% were men, 61.7% women, and their age was predominantly between 18 and 25 years old (51.4%). The 2.8% of the responders were teenagers, 18.1% between 26 and 35 years old, 11.1% between 36 and 45 years old, 8.3% between 46 and 55 years old and also 8.3% over 55 years of age. From the data process completion we resulted that the education level of the responders was high, as 26.4% graduated Highschool and 73.4% University. Among the responders, 16.7% worked in public sector, 33.3% in private sector, 5.5% were self-employed, 22.2% students and 22.3% unemployed. One useful result of this research was the change of the citizens' income during the years of economic crisis (2008-2012). Responders stated their tax free personal annual income from a scale table in order to explore their willingness to pay for traffic noise related projects. Only 5.5% of the responders stated the highest income scale for the year 2008 and nobody for 2012 (>20,000€). Higher income scale stated the 18.1% for the year 2008 and 2.8% for 2012 (15,000€ - 20,000€). Medium income scale stated the 22.2% for the year 2008 and 23.6% for 2012 (10,000€ - 15,000€). Lower income scale stated the 30.5% for the year 2008 and 40.3% for 2012 (5,000€ - 10,000€). Finally, the lowest income scale stated the 23.6% of the responders in 2008 and 33.3% in 2012 (<5,000€).

3.2. Active Living and Traffic Noise

Among the responders, 16.7% answered that urban traffic noise in the city of Volos has been increased during the years 2008-2012, 48.6% that has been decreased, 27.8% that is stable and 6.9% has no opinion. The responders have been asked if urban traffic noise affects their route selection to reach their destination. The 6.9% answered that is "unimportant", 33.3% that is "very important" and only 8.3% that is "critical" (Table 1). They have been asked if urban traffic noise affects transportation mode selection. The 19.4% answered that is "unimportant", 16.6% that is "very important" and only 6.9% that is "critical" (Table 1). They have also been asked if they would prefer walking more in case of traffic noise reduction. Only the 9.7% answered that is "unimportant", 34.7% that is "very important" and 11.1% that is "critical" (Table 1). Finally, they have also been asked if they would prefer cycling more in case of traffic noise reduction. Only the 6.9% answered that is "unimportant", 25% that is "important" and 15.2% that is "critical" (Table 1).

Table 1: Traffic noise and active living

Rating Scale	*Unimportant*	*Slightly Important*	*Important*	*Very Important*	*Critical*
Question	Does urban traffic noise affect route selection?				
Answer	6,9%	16,6%	34,7%	33,3%	8,3%
Question	Does urban traffic noise affect transportation mode selection?				
Answer	19,4%	33,3%	23,6%	16,6%	6,9%
Question	If the urban traffic noise was reduced, would you prefer walking more?				
Answer	9,7%	19,4%	25,0%	34,7%	11,1%
Question	If the urban traffic noise was reduced, would you prefer cycling more?				
Answer	6,9%	16,6%	36,1%	25,0%	15,2%

The responders had to select for projects relative to traffic noise reduction. The 9.7% of the responders selected the alternative of traffic speed reduction, 16.7% traffic flow reduction, 26.4% construction or extension of the bikeway network, 4.2% improvement of pedestrian facilities, 25% implementation of traffic calming streets and 18% construction of pedestrian streets.

The responders had to assess the level of traffic noise is the street where their residence was. The 18.1% characterized the traffic noise being “low”, 51.4% “moderate” and 30.5% “high” (Table 2). They also stated if they preferred living in a quieter but more expensive neighbourhood. The 25% of the citizens stated that is “unimportant”, 44% “moderate” and 30.6% “critical” (Table 2). Regarding the impacts of traffic noise for public health, the 15.3% stated that is “unimportant”, 41.6% “moderate” and 43.1% “high” (Table 2). Regarding the impacts of sustainable transport modes in traffic noise reduction, the 12.5% stated that is “unimportant”, 18.1% “moderate” and 69.4% “high” (Table 2).

The responders had to answer which transport mode or combination of ones they promoted in order to decrease traffic noise levels. The 33.3% of the responders answered that preferred walking, 15.3% cycling, 16.7% public transport (bus, tramway, metro) and a remarkable 34.7% combined transportation (bike on public transport).

Table 2: Traffic noise and built environment

Rating Scale	*Low*	*Moderate*	*High*
Question	What is the level of traffic noise in the street where is your residence?		
Answer	18,1%	51,4%	30,5%
Rating Scale	*Unimportant*	*Moderate*	*Critical*
Question	Do you prefer living in a quieter but more expensive neighborhood?		
Answer	25,0%	44,4%	30,6%
Question	Do you consider that traffic noise level is important for public health?		
Answer	15,3%	41,6%	43,1%
Question	Do you consider that sustainable transport modes reduce traffic noise?		
Answer	12,5%	18,1%	69,4%

A final question of this research was the statement of the citizens’ willingness to pay an annual amount of money in euro, for traffic noise reduction projects or promotion of sustainable transportation projects. The 9.7% refused to pay, 36.1% selected the lower scale (1€-10€), 26.4% selected the medium scale (11€-20€), 18.1% selected the high scale (21€-30€) and finally the 9.7% selected the highest scale (>30€). About 13.7€ was the average amount of money each citizen was willing to pay annually. Considering the population of the city, the total available annual budget was 2 million euro, which is an important fund in the era of financial crisis. Only 15.3% of the responders stated they trust local authorities to use this fund and implement relative projects. The 23.6% stated a moderate opinion and the majority of citizens (61.1%) stated they did not trust local authorities, decision makers and politicians to manage this fund.

4. Conclusions

Traffic noise reduction requires the implementation of different projects in urban built environment, transportation planning and vehicles' technology. In this research, a survey about citizens' point of view in urban traffic noise and sustainable transportation in the city of Volos was conducted. The main findings of the research were the following:

- Traffic noise could affect commuters' route selection in daily urban trips as responders stated it being "very important" or "critical" (41.6%).
- Traffic noise moderately affects transport mode selection in commuters' daily urban trips as responders stated it being "very important" or "critical" (23.5%).
- Traffic noise reduction importantly increases sustainable transportation as responders stated it being "very important" or "critical" (45.8% walking and 40.2% cycling).
- Traffic noise bothers citizens who wish living in a quieter neighbourhood even if the rent is higher (30.5%).
- Citizens acknowledge the negative impacts of traffic noise for public health (43.1%).
- Citizens acknowledge the positive impacts of sustainable transportation as an asset to reduce urban traffic noise (69.4%).
- Citizens are willing to pay 13.7€ annually, for traffic noise reduction projects and promotion of sustainable transportation but they do not trust local authorities, decision makers and politicians to implement these projects and manage the fund (61.1%).

Promotion of sustainable transportation could be a financially affordable solution in order to reduce the level of urban traffic noise in the era of economic crisis.

ACKNOWLEDGMENTS

The authors would like to thank the University of Thessaly, Department of Civil Engineering undergraduate student Anastasio Siapo for his contribution in the data collection process of this research. Furthermore, the authors would like to thank all responders for their participation, reporting that no sensitive personal data were asked or explored from other sources for process during this research.

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Οικονομικοτεχνικοί παράγοντες που επηρεάζουν τα έργα διάνοιξης του δάσους στην ορεινή περιοχή του Μετσόβου με σκοπό τη βιώσιμη ανάπτυξή της

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ΠΕΡΙΛΗΨΗ

Η βιώσιμη ανάπτυξη των ορεινών περιοχών επιτυγχάνεται με την αειφορική διαχείριση των δασικών οικοσυστημάτων, η οποία αποτελεί θεμελιώδη αρχή για τη δασική πολιτική της χώρας μας. Η αειφορική διαχείριση των δασών προϋποθέτει βέβαια, την ύπαρξη των απαραίτητων υποδομών (ολοκληρωμένη διάνοιξη των δασών). Η κατασκευή των δασικών οδικών δικτύων προκαλεί επιπτώσεις στο δασικό οικοσύστημα και το περιβάλλον γενικότερα. Οι επιπτώσεις αυτές μπορούν εν μέρει μόνο να αποκατασταθούν, αλλά στις περισσότερες των περιπτώσεων είναι αδύνατο να γίνει αυτό, αφού τα παραγωγικά δάση της χώρας μας βρίσκονται κυρίως σε ορεινές περιοχές με έντονο τοπογραφικό ανάγλυφο, δυσμενείς εδαφολογικές συνθήκες και ανομοιόμορφη κατανομή της δασικής βλάστησης, παράγοντες οι οποίοι δημιουργούν πολλές δυσχέρειες στο σχεδιασμό, τη χάραξη και την κατασκευή των δασικών δρόμων. Το γεγονός αυτό, απαιτεί ιδιαίτερη μελέτη των συνθηκών που επικρατούν σε κάθε περιοχή ξεχωριστά και των παραγόντων που επηρεάζουν την οδική διάνοιξη των δασών ή επηρεάζονται από αυτήν, με σκοπό τη σύνταξη ολοκληρωμένων σχεδίων διάνοιξης, τα οποία βέβαια λαμβάνουν υπόψη τους και την προστασία του περιβάλλοντος. Σκοπός της εργασίας αυτής είναι η ολοκληρωμένη οδική διάνοιξη της ορεινής περιοχής του δήμου Μετσόβου με βάση τα οικονομικά, τεχνικά και οικολογικά κριτήρια της περιοχής. Για την επίτευξη του σκοπού της έρευνας χρησιμοποιήθηκαν δασοπονικά στοιχεία (ξυλαπόθεμα, προσαύξηση, λήμμα), οικονομικά στοιχεία (κόστος κατασκευής και συντήρησης των δασικών δρόμων, κόστος μετατόπισης του ξύλου, καθώς και η αξία του εδάφους της ζώνης κατάληψης) και εδαφοτεχνικά στοιχεία. Με την επεξεργασία των παραπάνω στοιχείων καθορίστηκε η άριστη οδική πυκνότητα καθώς και η σχέση της με τους παραπάνω παράγοντες.

Λέξεις κλειδιά: Προσαύξηση, εδαφική πρόσοδος, δαπάνες συντήρησης, οδική πυκνότητα, ξυλαπόθεμα.
JEL κωδικοί: Q01, Q23, Q56

Abstract

The viable development of the mountainous regions is achieved with the sustainable management of the forest ecosystems. This principle composes the base of the forest politics in Greece. The sustainable management of the forests requires of course, the existence of the necessary substructure (integrated forest opening up). The construction of the forest road networks causes effects to the forest ecosystem and to the environment in general. These effects can only be partly restored, but in most of the cases this is impossible, since the country's productive forests are located mainly in the mountainous areas with strong topographic adverse, with territorial conditions and uneven distribution of the forest vegetation. These factors may cause many difficulties to the planning, to the mapping out and to the construction of the forest roads. This fact demands particular study of the conditions that prevail to each region separately and of the factors that affect the forest road opening up works or they are affected by it, so as to draft integrated plans of the forest opening up works taking under consideration the preservation of the environment. The purpose of this work is the integrated forest opening up of the mountainous region of the Municipality of Metsovo taking under consideration the technical, economical, ecological and social criteria of this region. For the achievement of the goals of the study there have been set forestry elements (wood supply, wood increment and lemma), financial elements (cost construction and preservation of the forest roads, logging cost and the value of earth of the coverage zone) and territorial elements. With the elaboration of the above data, the optimum road density has been determined as well as the relevance with it.

Εισαγωγή

Τα ορεινά οικοσυστήματα αποτελούν σημαντική πηγή φυσικών πόρων, εκφράζοντας επίσης την πολυπλοκότητα και τις αλληλεπιδράσεις της οικολογίας του πλανήτη μας. Ωστόσο μεταβάλλονται ταχύτατα.

Η βιώσιμη ανάπτυξη των ορεινών περιοχών αποτελεί κύριο σκοπό της δασικής πολιτικής στην χώρα μας και στις περισσότερες των περιπτώσεων προϋποθέτει ανθρωπογενείς επεμβάσεις στο φυσικό περιβάλλον, οι συνέπειες των οποίων πολλές φορές οδηγούν στην αλλοίωση και υποβάθμιση του (Ταμπέκης, 2009).

Σκοπός της εργασίας αυτής είναι η έρευνα που αφορά την ολοκληρωμένη οδική διάνοιξη της ορεινής περιοχής του δήμου Μετσόβου με βάση οικονομικά στοιχεία (κόστος κατασκευής και συντήρησης των δασικών δρόμων, κόστος μετατόπισης του ξύλου, καθώς και αξία του εδάφους της ζώνης κατάληψης), δασοπονικά στοιχεία (ξυλαπόθεμα, προσαύξηση, λήμμα) και εδαφοτεχνικά στοιχεία της περιοχής. Από την επεξεργασία των παραπάνω στοιχείων καθορίστηκε η άριστη οδική πυκνότητα και εξετάστηκε η επίδραση των παραπάνω παραγόντων στο μέγεθος της άριστης οδικής πυκνότητας.

Δεδομένα και Μέθοδοι

Δεδομένα

Ως περιοχή έρευνας επιλέχθηκαν τα δασικά τμήματα 3 και 4 του δημοτικού δάσους του δήμου Μετσόβου, νομός Ιωαννίνων. Στην περιοχή έρευνας το πραγματικό ξυλαπόθεμα για την δεκαετία 2005-2014, (Διαχειριστική Κλάση Μαύρης Πεύκης) ανέρχεται σε 92570 m^3. Στο συνολικό ξυλαπόθεμα εκτός της Μαύρης Πεύκης περιλαμβάνονται και η Λευκόδερμος Πεύκη με την Οξιά, ενώ το συνολικό λήμμα ανέρχεται σε 4839 m^3/δεκαετία για την συνολική έκταση των συγκεκριμένων τμημάτων, άρα ο μέσος όρος είναι 1,86 m^3/ha/έτος, που αποτελεί και την ετήσια κάρπωση στα τμήματα 3 και 4.

Ακόμη για τις ανάγκες της έρευνας χρησιμοποιήθηκαν: α) ορθοφωτοχάρτες και τα διαγράμματα των ορθοφωτοχαρτών (κλίμακας 1:5000) και τα αντίστοιχα μοντέλα εδάφους (DTM), β) η διαχειριστική μελέτη από την Δασική Υπηρεσία Μετσόβου του δημοτικού δάσους του δ/δ Μετσόβου περιόδου 2005-2014, γ) οι αναλυτικές Τιμές Έργων Οδοποιίας (ΑΤΕΟ) και Υδραυλικών Έργων (ΑΤΕΥΔ) 2ου τριμήνου 2006 και δ) τα λογισμικά AutoCAD Civil 3D 2013 και ArcGIS.

Μεθοδολογία

Σχέσεις δαπανών και οδικής πυκνότητας

Η τιμή της οδικής πυκνότητας D επηρεάζεται σημαντικά από τα έξοδα που απαιτούνται τόσο για τη κατασκευή και συντήρηση του οδικού δικτύου, όσο και για τη μετακίνηση του ξύλου και αφετέρου από την απώλεια της εδαφικής προσόδου (Καραγιάννης, 1991, Ταμπέκης, 2009) όπως δίνονται στις παρακάτω σχέσεις:

1. Εδαφική πρόσοδος

Η κατασκευή των δασικών δρόμων καταστρέφει παραγωγική δασική επιφάνεια, η έκταση της οποίας είναι ίση με την επιφάνεια που θα καταλάβει το κατάστρωμα και τα πρανή του δασικού δρόμου (ζώνη κατάληψης). Η απώλεια της εδαφικής προσόδου που προέρχεται από την καταστροφή της παραγωγικής δασικής επιφάνειας υπολογίζεται από τη σχέση (Στεργιάδης, Στάμου, 1982, Στεργιάδης, Δούκας, 1983-1984, Καραγιάννης, 1991, Ταμπέκης, 2009):

$$K_B = b*B*0.0p*D \qquad (1)$$

όπου συμβολίζουν:

K_B : Την εδαφική πρόσοδο σε ευρώ/τρ. μ. δασικού δρόμου

b : Το πλάτος σε μέτρα της ζώνης που καταλαμβάνει ο δασικός δρόμος

B : Την αξία του εδάφους σε ευρώ/m^2

p : Το επιτόκιο σε ποσοστό % και

D: Την οδική πυκνότητα.

Οι τιμές των συντελεστών για τη περιοχή έρευνας ανέρχονται σε F= 2.41, W=1.504.

Ο συντελεστής ελιγμών W είναι ο λόγος του πραγματικού μήκους των δασικών δρόμων προς το ευθύγραμμο μήκος αυτών, αν οι δασικοί δρόμοι ήταν ευθύγραμμοι. Επηρεάζεται από τη μορφολογία του εδάφους. Στον υπολογισμό του συντελεστή εδάφους F λαμβάνεται υπόψη η διαμόρφωση του εδάφους και η επίδραση της στο μήκος των δασικών δρόμων και χρησιμοποιείται για τη διόρθωση της διάταξης των δασικών δρόμων στο έδαφος.

Με βάση τις Ελληνικές δασοπονικές συνθήκες και την οικονομική κατάσταση που επικρατεί σαν επιτόκιο επιλέγεται το 3%.

Η κατασκευή κάθε δασικού δρόμου προκαλεί μείωση της παραγωγικής επιφανείας του δάσους. Η μείωση αυτή εξαρτάται κυρίως από το πλάτος του δασικού δρόμου, τη εγκάρσια κλίση του εδάφους που κατασκευάζεται ο δασικός δρόμος και τις κλίσεις των πρανών του. Το πλάτος της ζώνης καταλήψεως που καταλαμβάνουν οι δασικοί δρόμοι στη περιοχή έρευνας υπολογίστηκε για την Α΄ κατηγορία δασικών δρόμων σε 16.65 m, με μήκος 6294.04 m και για την Γ΄ κατηγορία δασικών δρόμων σε 10.33 m, με μήκος 10125.38 m.

Οπότε είναι: $$b=\frac{6294.04}{16419.42}*16.65+\frac{10125.38}{16419.42}*10.33=12.73\text{m}.$$

Ο υπολογισμός της αξίας του εδάφους στην περιοχή υπολογίζεται ως εξής: Το κάθε εκτάριο των δασικών τμημάτων παράγει και θα παράγει κατά τη διάρκεια της χρήσης του οδικού δικτύου ορισμένη ποσότητα κατά μέσο όρο κυβικών μέτρων ξύλου, σαν ετήσιο λήμμα. Το λήμμα αυτό αν μετατραπεί σε αξία, με βάση τις τιμές που πωλείται στην αγορά, αποτελεί την ετήσια χρηματική πρόσοδο για ένα εκτάριο. Η χρηματική αυτή πρόσοδος αν θεωρηθεί πως είναι αειφορική, μπορεί με την κεφαλαιοποίησή της, να δώσει την αξία για ένα εκτάριο του δασικού εδάφους μαζί με το ξυλαπόθεμα, σύμφωνα με τον τύπο (Στεργιάδης, Στάμου 1982, Καραγιάννης, 1991):

$$B=\frac{A}{0.0p} \qquad (2)$$

(όπου: Β: η ζητούμενη αξία του εδάφους σε ευρώ/ha, Α: η ετήσια χρηματική πρόσοδος σε ευρώ/ha και p: το επιτόκιο της κεφαλαιοποίησης).

Η μέση απόσταση μετατόπισης REm υπολογίστηκε ψηφιακά και βρέθηκε ότι κυμαίνεται από 96.34m έως 231.48m. Ειδικότερα υπολογίστηκε ως εξής: Πάνω στη περιοχή μελέτης και στον ψηφιακό χάρτη αυτής, τοποθετήθηκε επίπεδο τετραγωνισμένο πλέγμα (δικτυωτό) πλευράς 100 m. Μετρήθηκε πάνω στον χάρτη που προέκυψε ψηφιακά, η ευθύγραμμη απόσταση κάθε κορυφής των τετραγώνων που ήταν μέσα στην περιοχή έρευνας (δασικά τμήματα 3 και 4) από τον κοντινότερο δασικό δρόμο. Η κάθε κορυφή αποτελεί την θέση υλοτομίας (υλοτόμιο). Έτσι μετράται η ευθύγραμμη απόσταση που διανύεται από την θέση υλοτομίας στον κοντινότερο δασικό δρόμο.

Η μετατροπή του λήμματος σε χρηματική πρόσοδο πραγματοποιήθηκε με βάση τις τρέχουσες τιμές του έτους 2007. Η αξία ανά m^3 λήμματος βασίστηκε στη σύνθεση του λήμματος από τα διάφορα επιμέρους προϊόντα που δίνονται στη διαχειριστική μελέτη περιόδου 2005-2014 του δημοτικού δάσους Μετσόβου και στις αντιστοιχίες ανά μονάδα προϊόντος για τις τιμές της αγοράς για το έτος 2007.

Από τη διαχειριστική μελέτη περιόδου 2005-2014 για το δημοτικό δάσος Μετσόβου και τα αποληφθέντα προϊόντα στα τμήματα 3 και 4 του δάσους, προκύπτει ότι η αναλογία τεχνικής ξυλείας και καυσόξυλων είναι: 82% τεχνική ξυλεία και 18% καυσόξυλα. Πρόκειται για τεχνική ξυλεία και καυσόξυλα Μαύρης Πεύκης και Οξιάς αντίστοιχα. Στην εν λόγω περιοχή επικρατεί η Μαύρη Πεύκη κατά 96.72% και η Οξιά κατά 3.28%. Οι τιμές για τις αντίστοιχες κατηγορίες δασικών προϊόντων στην αγορά δίνονται στον Πίνακα 1:

Πίνακας 1: Πίνακας Διατίμησης Δασικών Προϊόντων Διαχειριστικού έτους 2007. ΦΕΚ.90/Τεύχος Β΄/30-1-2007.

	Τιμές Δασικών Προϊόντων			
Δασ. Προϊόν	Τεχνική Ξυλέια (ευρώ/κ.μ.)		Καυσόξυλα (ευρώ/χ.κ.μ.)	
Δασ. Είδος	Μ. Πεύκη	Οξιά	Μ. Πεύκη	Οξιά
Αξία σε ευρώ	52.19	65.55	8.04	17.49

Οπότε:

I. Τεχνική ξυλεία: 0.82(0.9672*52.19+0.0328*65.55)=43.16 €/m^3.

II. Καυσόξυλα: 0.18(0.9672*8.04+0.0328*17.49)*1.49=2.24 €/m^3.

(0.67 συντελεστής μετατροπής των χ.κ.μ. σε m^3.)

Συνολικά λοιπόν η αξία τεχνικής ξυλείας και καυσόξυλου είναι 43.16+2.24=45.40 €/m^3.

Άρα η ζητούμενη αξία του εδάφους είναι: Β=$\frac{1.86*45.40}{0.03}$=2814.8 €/ha ή 0.28 €/m^2.

Αν τώρα η εδαφική πρόσοδος συσχετιστεί με την οδική πυκνότητα που ανάγεται στην ποσότητα του ξύλου (Ν) που παράγεται στη μονάδα επιφάνειας, τότε προκύπτει η σχέση:

$$K_B = \frac{b*B*0.0p}{N}*D \qquad (3)$$

Όπου b=12.73m B=0.28ευρώ/m^2 p=3% Ν = η παραγόμενη ποσότητα ξύλου 1.86m^3/ha/έτος.

Άρα $$K_B=\frac{12.73*0.28*0.03}{1.86}*D=0.06D \qquad (4)$$

2. Απόσβεση και τόκος κεφαλαίου που επενδύεται για κατασκευή δασικών δρόμων

Το ετήσιο τοκοχρεωλύσιο των εξόδων κατασκευής των δασικών δρόμων σε συνάρτηση με την οδική πυκνότητα και την ετήσια κάρπωση υπολογίζεται από τον τύπο (Στεργιάδης, Δούκας, 1983-1984, Καραγιάννης 1991, Ταμπέκης, 2009):

$$K_R=\frac{A}{N}*\frac{1.0p^n*0.0p}{1.0p^n-1}*D \qquad (5)$$

όπου είναι:

K_R: Ετήσιο τοκοχρεωλύσιο των εξόδων κατασκευής των δασικών δρόμων

A: Κόστος κατασκευής δασικών δρόμων ευρώ/τρ. μ.

D: Οδική πυκνότητα m/ha

n: Διάρκεια σε χρόνια για την απόσβεση των κεφαλαίων που χρειάζονται για την κατασκευή δασικών δρόμων

p: Επιτόκιο σε ποσοστά %

N: Η ποσότητα ξύλου που λαμβάνεται από το δάσος σε m^3/ha.

Η χρονική διάρκεια για την απόσβεση των κεφαλαίων που χρειάζονται για την κατασκευή των δασικών δρόμων είναι για τις Ελληνικές δασοπονικές συνθήκες τα 30 χρόνια. Το κόστος κατασκευής των δασικών δρόμων όπως προέκυψε από την επιτόπια έρευνα στην περιοχή του δήμου Μετσόβου και τη ψηφιοποίηση του αλλά και με βάση το τιμολόγιο του ΑΤΕΟ Έργων Οδοποιίας και ΑΤΕΥΔ Υδραυλικών Έργων του $2^{ου}$ τριμήνου του 2007 (Γ.Γ.Δ.Ε. 2007) ανέρχεται σε 135.64 €/m. για τους δασικούς δρόμου Α΄ κατηγορίας και σε 10.89 €/m για τους δασικούς δρόμου Γ΄ κατηγορίας.

Άρα: $$A=\frac{6294.04}{16419.42}*135.64+\frac{10125.38}{16419.42}*10.89=51.51+6.75=58.29 \text{ €/m.}$$

n= 30 χρόνια, για την απόσβεση των κεφαλαίων που χρειάζονται για την κατασκευή δασικών δρόμων

p= 3%

N= 1.86m^3/ha.

Τότε το ετήσιο τοκοχρεολύσιο που προέρχεται από τα έξοδα κατασκευής δασικών δρόμων εκφράζεται σε συνάρτηση με την οδική πυκνότητα από την εξής σχέση:

$$K_R=\frac{58.29}{1.86}*\frac{1.03^{30}*0.03}{1.03^{30}-1}*D=1.59D \qquad (6)$$

3. Δαπάνες συντήρησης

Οι δαπάνες που χρειάζονται για τη συντήρηση των δασικών δρόμων και που επιβαρύνουν κάθε κυβικό μέτρο ξύλου που παράγεται στο δασικό σύμπλεγμα υπολογίζονται από την παρακάτω σχέση (Στεργιάδης, Δούκας, 1983-1984, Καραγιάννης, 1991, Ταμπέκης, 2009):

$$K_{SU}=\frac{Su}{N}*D \qquad (7)$$

όπου είναι:

S_U: ετήσιες δαπάνες συντήρησης €/τρ. μ.

N: ετήσια κάρπωση σε m^3/ha.

Από την έρευνα που πραγματοποιήθηκε στην περιοχή έρευνας προέκυψε ότι οι ετήσιες δαπάνες συντήρησης ανέρχονται σε 0.42 €/τρ.μ. Το κόστος συντήρησης υπολογίστηκε βάση των τιμών ΑΤΕΟ $2^{ου}$ τριμήνου 2006. Επομένως είναι:

S_U: 0.42 €/τρ. μ.

N: 1.86 m^3/ha.

Άρα $K_{SU}=\frac{0.42}{1.86}*D=0.23D$ (8)

4. Δαπάνες μετατόπισης

Ο υπολογισμός των δαπανών που χρειάζονται για τη μετατόπιση του ξύλου γίνεται με την εφαρμογή της παρακάτω σχέσης που ισχύει στη μονόπλευρη μετατόπιση αφού ο υπολογισμός του κόστους μετατόπισης πραγματοποιείται με βάση το μήκος της σύρτας (Στεργιάδης, Δούκας, 1983-1984, Καραγιάννης, 1991, Ταμπέκης, 2009):

$$Kr=E\pi+E\mu*REt= E\pi+ E\mu*\frac{5000}{D}*F*W \quad (9)$$

Όπου συμβολίζουν:

Επ: Τα σταθερά (πάγια) έξοδα της μετατόπισης του ξύλου σε ευρώ/κ. μ.

Εμ: Τα μεταβλητά έξοδα μετατόπισης του ξύλου σε ευρώ/κ. μ./τ.μ.

REt: Την πραγματική μέση απόσταση μετατόπισης.

F: Τον συντελεστή εδάφους.

W: Τον συντελεστή ελιγμών.

Το σταθερό κόστος μετατόπισης Επ είναι ανεξάρτητο από την απόσταση μετατόπισης και εξαρτάται από τη μεταφορά του εξοπλισμού μετατοπίσεως στον τόπο υλοτομίας, τις εργασίες προετοιμασίας, την αναζήτηση των κορμοτεμαχίων που πρόκειται να μετατοπιστούν, τη φόρτωση ή πρόσδεση των κορμοτεμαχίων, την απομάκρυνση τυχόν εμποδίων, το ξεφόρτωμα ή την αποσύνδεση των φορτιών και την αποθήκευσή τους (ταξινόμηση ή στοίβαξη) στον τόπο συγκεντρώσεως.

Το μεταβλητό κόστος μετατόπισης Εμ εξαρτάται από την μέση απόσταση μετατόπισης REt και επηρεάζεται από τις εδαφικές συνθήκες, τις κλιματικές συνθήκες, από τον απολαμβανόμενο όγκο ξύλου στη μονάδα επιφανείας, από τις διαστάσεις των κορμοτεμαχίων, τη μέθοδο και τα μέσα μετατόπισης, τον όγκο του φορτίου, την απόδοση των μετατοπιστών, των ζώων και των μηχανημάτων, την οργάνωση της εργασίας μετατόπισης και την απόσταση μετατόπισης.

Τα έξοδα μετατόπισης του ξύλου (Επ σταθερά και Εμ μεταβλητά) υπολογίζονται με βάση τις Τιμές Ανάθεσης Δασικών Προϊόντων έτους 2007, ΦΕΚ, 85238/137/12-1-2007 που καθορίζονται από τη Δασική Υπηρεσία Μετσόβου για την μετατόπιση ξύλου κωνοφόρων και πλατύφυλλων ειδών με τη βοήθεια γραμμικών εξισώσεων πρώτου βαθμού (Πίνακας 2) για την περίπτωση της μετατόπισης του ξύλου σε απόσταση x≤500m, αφού η απόσταση μετατόπισης υπολογίστηκε προηγούμενα και ανέρχεται σε 146.76m.

Πίνακας 2: Εξισώσεις* υπολογισμού δαπανών μετατόπισης του ξύλου σε συνάρτηση απόσταση μετατόπισης που δίνονται από τη Δασική Υπηρεσία, έτος 2007.

Κατηγορία ξύλου	Απόσταση (m)	Μ. Πεύκη	Πλατύφυλλα Οξιά
Τεχνικό ξύλο άφλοιο (κ.μ.)	x≤500	3.68+1.32x**	4.18+1.60x**
Καυσόξυλο άφλοιο (ευρώ/χ.κ.μ./τρ.μ.)	x≤500	2.60+0.98x**	3.43+0.98x**

*Τιμές Ανάθεσης Δασικών Προϊόντων έτους 2007, ΦΕΚ, 85238/137/12-1-2007.

**x η απόσταση μετατόπισης σε εκατόμετρα

Στα τμήματα 3 και 4 του δημοτικού δάσους Μετσόβου συμμετέχουν στη σύνθεση των τμημάτων 96.72% κωνοφόρα (Μαύρη Πεύκη) και 3.28% πλατύφυλλα (Οξιά) και το ξύλο που υλοτομείται από τη δασική αυτή περιοχή είναι 82% τεχνική ξυλεία και 18% καυσόξυλα.

α) Σταθερά έξοδα μετατόπισης
Ι. Τεχνικό ξύλο 82%.
$Eπ_1=0.82(0.9672*3.68+0.0328*4.18)=3.03\ m^3$
ΙΙ. Καυσόξυλα 18%.
$Eπ_2=0.18(0.9672*2.6+0.0328*3.43)*1.49=0.70\ m^3$
(0.67 συντελεστής μετατροπής των χ.κ.μ. σε m^3)
Επομένως τα συνολικά σταθερά έξοδα είναι:
$Eπ= Eπ_1+ Eπ_2=3.03+0.70=3.73\ m^3$
β) Μεταβλητά έξοδα μετατόπισης
Ι. Τεχνικό ξύλο 82%.
$Eμ_1=0.82(0.9672*1.32+0.0328*1.60)=1.09\ m^3$
ΙΙ. Καυσόξυλα 18%.
$Eμ_2=0.18(0.9672*0.98+0.0328*0.98)1.49=0.26\ m^3$
(0.67 συντελεστής μετατροπής των χ.κ.μ. σε m^3)
Άρα τα συνολικά μεταβλητά έξοδα μετατόπισης είναι:
$Eμ= Eμ_1+ Eμ_2=1.09+0.26=1.35\ m^3$

Η συνολική εξίσωση υπολογισμού των δαπανών μετατόπισης για τη συγκεκριμένη σύνθεση των τμημάτων 3 και 4 που αναφέρθηκε παραπάνω είναι:

$$3.73+1.35\ REt\ €/\ m^3 \qquad (10)$$

Αν στην εξίσωση αυτή προστεθούν 10% προσαύξηση λόγω κλίσης (μέση κλίση 35-70%) και 10% προσαύξηση λόγω της απόστασης (≤50Km) της έδρας των αγοραστών της ξυλείας (Δασικός Συνεταιρισμός Μετσόβου) από το υλοτόμιο.
Έτσι η τελική εξίσωση μετατόπισης γίνεται:

$$1.2*(3.73+1.35)=4.48+1.62\ REt\ €/\ m^3 \qquad (11)$$

Σταθερά έξοδα μετατόπισης: 4.48 €/ m^3.

$$\text{Μεταβλητά έξοδα μετατόπισης: } \frac{1.62}{100} * REt=0.0162\ REt\ €/\ m^3 \qquad (12)$$

Τελικά προκύπτει:

$$Kr=4.48+0.0162*\frac{5000}{D}*2.41*1.504=4.48+0.0162*\frac{18123.2}{D}=4.48+\frac{293.6}{D} \qquad (13)$$

από την οποία προκύπτει και η τιμή της πραγματικής απόστασης μετατόπισης REt που δίνεται σε συνάρτηση προς την οδική πυκνότητα D από τη σχέση:

$$REt=\frac{18123.2}{D} \qquad (14)$$

Αποτελέσματα

Οικονομικά άριστη οδική πυκνότητα έχουμε όταν τα έξοδα μετατόπισης του ξύλου Kr είναι ίσα με τα συνολικά έξοδα κατασκευής και συντήρησης των δασικών δρόμων K_W, τα οποία για τη περίπτωση μας εκφράζονται σε συνάρτηση με την οδική πυκνότητα D με τη σχέση:

$$K_W= K_B+K_R+K_{SU}=0.06D+1.59D+0.23D=1.88D \qquad (15)$$

Από τα προηγούμενα στοιχεία προκύπτει η τιμή της οικονομικά άριστης οδικής πυκνότητας που υπολογίζεται ως εξής:

$$K_W= Kr \qquad \text{ή } 1.88D=4.48+\frac{293.6}{D}$$

$$\text{ή } 1.88D^2-4.48D-293.6=0 \qquad (16)$$

Με την επίλυση της δευτεροβάθμιας εξίσωσης (16) προκύπτει ότι **D_{OIK}=13.75 m/ha**, η οποία είναι μικρότερη της Dυπ=28.31m/ha, η αρνητική λύση της δευτεροβάθμιας εξίσωσης απορρίπτεται.

Η θεωρητικά άριστη οδική πυκνότητα προκύπτει όταν τα συνολικά έξοδα κατασκευής και συντήρησης των δασικών δρόμων K_W μαζί με τα έξοδα μετατόπισης του ξύλου γίνουν ελάχιστα, δηλαδή:

$K_S = K_W + Kr$=ελάχιστα

ή $K_S = 1.88D + 4.48 + \dfrac{293.6}{D}$ =ελάχιστα.

Η παραπάνω σχέση ισχύει όταν η πρώτη παράγωγος της K_S γίνει ίση με το μηδέν,

$$\text{ή } \frac{\Delta Ks}{\Delta D} = 0 \qquad \text{ή } 1.88 - \frac{293.6}{D^2} = 0 \tag{17}$$

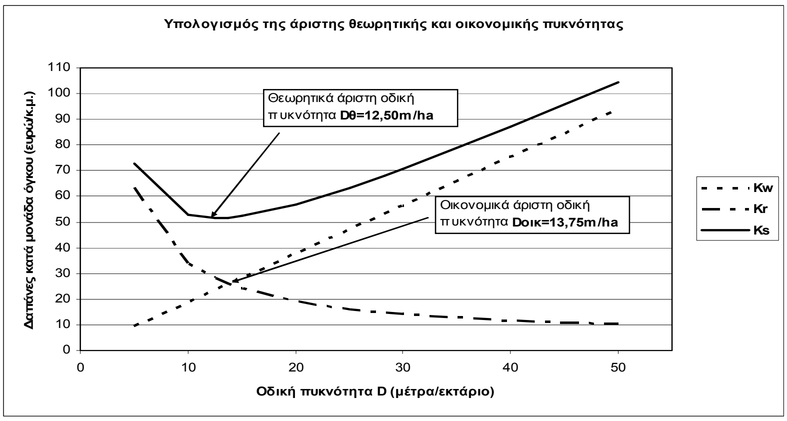
ή $D^2 = \dfrac{293.6}{1.88}$ ή **D_{Θ}=12.50m/ha**,

η οποία είναι μικρότερη της Dυπ=28.31m/ha, η αρνητική λύση της δευτεροβάθμιας εξίσωσης απορρίπτεται.

Με βάση τα στοιχεία της έρευνας των δασικών τμημάτων 3 και 4 του δημοτικού δάσους Μετσόβου υπολογίζονται η εδαφική πρόσοδος, το κόστος κατασκευής, το κόστος συντήρησης και το κόστος μετατόπισης αντίστοιχα από τις εξισώσεις (4), (6), (8) και (13) για διάφορες οδικές πυκνότητες.

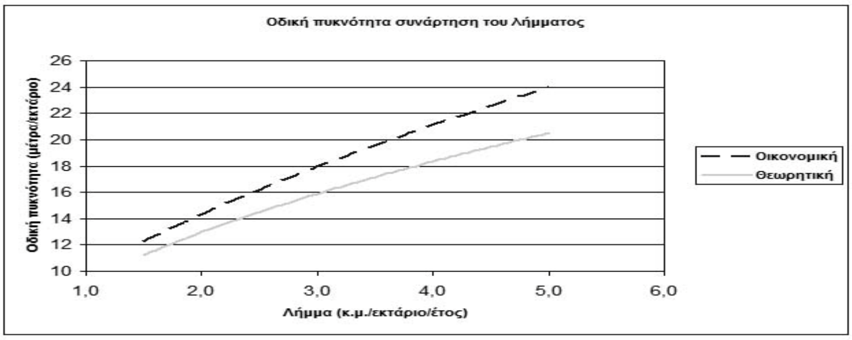
Υπολογίστηκε λοιπόν στα δασικά τμήματα 3 και 4 του δημοτικού δάσους Μετσόβου η υπάρχουσα οδική πυκνότητα δηλαδή η πυκνότητα που προκύπτει από τη σχέση Dυπ=L/F και ανέρχεται σε Dυπ=28.31m/ha, η οικονομική άριστη οδική πυκνότητα η οποία ανέρχεται σε D_{OIK}=13.75m/ha και η θεωρητικά άριστη οδική πυκνότητα που είναι D_{Θ}=12.50m/ha. Οι δυο τελευταίες υπολογίστηκαν με τη μέθοδο Kroth λαμβάνοντας υπόψη τόσο τις συνολικές δαπάνες κατασκευής και συντήρησης των δασικών δρόμων, καθώς και τις απώλειες της εδαφικής προσόδου όσο και τις συνολικές δαπάνες μετατόπισης του ξύλου (Kroth 1973).

Σχήμα 1: Δαπάνες οδικού δικτύου, μετατόπισης του ξύλου και συνολικές δαπάνες σε σχέση με την οδική πυκνότητα.



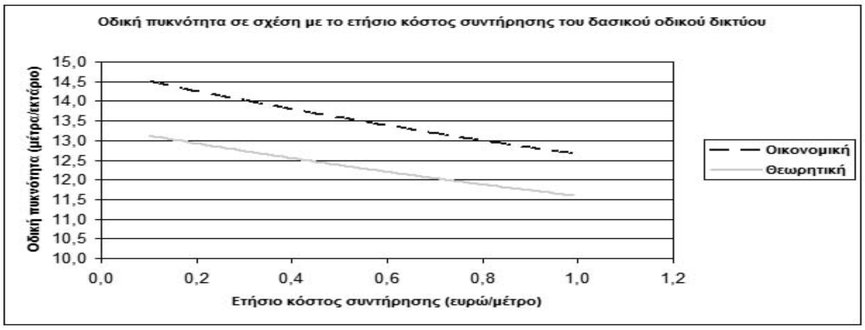
Στο σχήμα 2 φαίνεται πώς μεταβάλλεται η θεωρητικά και οικονομικά άριστη οδική πυκνότητα σε σχέση με το λήμμα N που παράγεται στη περιοχή (B=0.28 ευρώ/m^2, b=12.73m, p=3%, n= 30έτη, A=58.10ευρώ/m, Su=0.42ευρώ/m, Eπ=4.48ευρώ/m^3, Eμ=0.0162REt ευρώ/m^3, F=2.41, W=1.504).

Σχήμα 2: Η οδική πυκνότητα σε συνάρτηση με το λήμμα Ν στη περιοχή μελέτης.



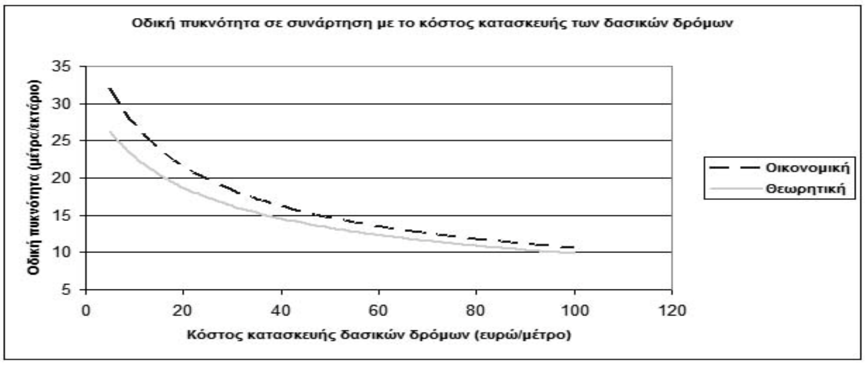
Στο Σχήμα 3 δίνεται πώς μεταβάλλεται η θεωρητικά και οικονομικά άριστη οδική πυκνότητα σε σχέση με το ετήσιο κόστος συντήρησης που απαιτείται για τη συντήρηση των δασικών δρόμων Α΄ και Γ΄ κατηγορίας στη (N=1.86m/ha, B=0.28 ευρώ/m^2 b=12.73m, p=3%, n=30έτη, A=58.10ευρώ/m, Επ=4.48ευρώ/m^3, Εμ=0.0162REt ευρώ/m^3, F=2.41, W=1.504).

Σχήμα 3: Η οδική πυκνότητα σε συνάρτηση με το ετήσιο κόστος συντήρησης των δασικών δρόμων στη περιοχή έρευνας.



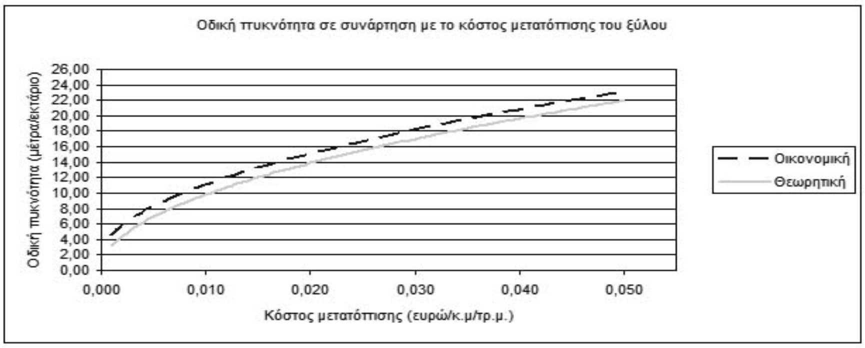
Στο σχήμα 4 φαίνεται πώς μεταβάλλεται η θεωρητικά και οικονομικά άριστη οδική πυκνότητα σε σχέση με το κόστος κατασκευής των δασικών δρόμων Α΄ και Γ΄ κατηγορίας στη περιοχή (N=1.86m/ha, B=0.28 ευρώ/m^2, b=12.73 m, p=3%, n=30έτη, Su=0.42ευρώ/m, Επ=4.48ευρώ/m^3, Εμ=0.0162Ret ευρώ/m^3, F=2.41, W=1.504).

Σχήμα 4: Η οδική πυκνότητα σε συνάρτηση με το κόστος κατασκευής των δασικών δρόμων στη περιοχή έρευνας.



Στο σχήμα 5 φαίνεται πώς μεταβάλλεται η θεωρητικά και οικονομικά άριστη οδική πυκνότητα σε σχέση με το κόστος μετατόπισης του ξύλου στη περιοχή (N=1.86m/ha, B=0.28 ευρώ/m^2, b=12.73 m, p=3%, n=30έτη, A=58.10ευρώ/m, Su=0.42ευρώ/m, Επ=4.48ευρώ/m^3, F=2.41, W=1.504).

Σχήμα 5: Η οδική πυκνότητα σε συνάρτηση με το κόστος μετατόπισης του ξύλου στη περιοχή έρευνας.



ΣΥΖΗΤΗΣΗ-ΣΥΜΠΕΡΑΣΜΑΤΑ

Με βάση τα αποτελέσματα της εργασίας προκύπτει ότι:

1. Όσο αυξάνει το λήμμα τόσο αυξάνει η θεωρητικά άριστη και η οικονομικά άριστη οδική πυκνότητα. Το ετήσιο λήμμα παράγεται στη παραγωγική δασική επιφάνεια και επηρεάζει την εδαφική πρόσοδο η οποία μειώνεται κατά τη κατασκευή των δασικών δρόμων (κατασκευή του καταστρώματος και των πρανών).

2. Με την αύξηση του κόστους συντήρησης μειώνεται τόσο η θεωρητικά άριστη όσο και η οικονομικά άριστη οδική πυκνότητα. Στις εργασίες συντήρησης συγκαταλέγονται εργασίες όπως η ισοπέδωση του καταστρώματος και ο καθαρισμός-μόρφωση τάφρου τριγωνικής διατομής. Το κόστος των εργασιών αυτών είναι αρκετά χαμηλότερο από το κόστος των εργασιών που απαιτούνται για τη κατασκευή του δασικού οδικού δικτύου και χαμηλότερο επίσης από τις δαπάνες που απαιτούνται για τη μετατόπιση της παραγόμενης ξυλείας.

3. Μειονέκτημα στον υπολογισμό με την μέθοδο Kroth της οικονομικής (Dοικ) και της θεωρητικά άριστης οδικής πυκνότητας (Dθ) είναι ότι δεν μπορούν να αποτιμηθούν σε χρηματικές μονάδες οι θετικές επιδράσεις των έργων διάνοιξης στη δασική εκμετάλλευση. Οι θετικές επιδράσεις που δημιουργούνται είναι: i) η προστασία από πυρκαγιές, ii) η ανάπτυξη πρώτα της τοπικής και κατόπιν της εθνικής οικονομίας (προσέγγιση των απαράμιλλης ομορφιάς δασικών τοπίων, ανάπτυξη αναψυχής, προσέγγιση γεωργικών εκτάσεων, μεταφορά γεωργικών προϊόντων, τροφοδότηση αγοράς με ξύλο, βελτίωση συγκοινωνίας με την επέκταση του επαρχιακού δικτύου, βελτίωση αγοράς εργασίας και δημιουργία νέων θέσεων εργασίας κ.ά.) iii) η διαχείριση υδάτινων πόρων (εύκολη προσέγγιση πηγών και υδρομαστεύσεων, κατασκευή έργων απόσβεσης χειμάρρων), iv) η συμβολή στην άμυνα της χώρας v) η συμβολή στη λιβαδοπονία κ.α. Ωστόσο. οι επιδράσεις αυτές καθορίζουν το μέγεθος της προσφοράς της διάνοιξης στην εκμετάλλευση και την προστασία των δασών και δεν συμβάλλουν όμως στον υπολογισμό της (Dοικ) και (Dθ), που γίνεται με βάση μόνο τα έσοδα που θα προκύψουν από τη μετατόπιση του ξύλου. Αντιθέτως, λαμβάνονται υπόψη κατά τον υπολογισμό της (Dοικ) και (Dθ) το κόστος κατασκευής και συντήρησης των δασικών δρόμων, το κόστος μετατόπισης του ξύλου και η απώλεια της εδαφικής προσόδου.

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ΚΑΤΑΛΟΓΟΣ ΣΥΜΜΕΤΕΧΟΝΤΩΝ

Συμμετέχοντες Φορείς – ΑΚΑΔΗΜΑΙΚΑ ΚΑΙ ΕΡΕΥΝΗΤΙΚΑ ΙΔΡΥΜΑΤΑ	
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14	Εθνικό Μετσόβιο Πολυτεχνείο, Σχολή Χημικών Μηχανικών Εργαστήριο Βιομηχανικής & Ενεργειακής Οικονομίας
15	ΕΚΕΦΕ Δημόκριτος, Εργαστήριο Περιβάλλοντος και Ραδιενέργειας, Ινστιτούτο Πυρηνικής Τεχνολογίας και Ακτινοβολίας
16	Ινστιτούτο Γεωργικών Ερευνών, Νικοσία, Κύπρος
17	METIS Accredited Observer to UNFCCC
18	Οικονομικό Πανεπιστήμιο Αθηνών, Τμήμα Διεθνών και Ευρωπαϊκών Οικονομικών Σπουδών
19	Πανεπιστήμιο Αιγαίου, Τμήμα Επιστημών της Θάλασσας
20	Πανεπιστήμιο Αιγαίου, Τμήμα Περιβάλλοντος
21	Πανεπιστήμιο Αιγαίου, Κέντρο Περιβαλλοντικής Πολιτικής και Στρατηγικής Περιβαλλοντικής Διαχείρισης, Τμήμα Περιβάλλοντος,
22	Πανεπιστήμιο Δυτικής Μακεδονίας
23	Πανεπιστήμιο Θεσσαλίας, Εργαστήριο Επιχειρησιακών Ερευνών, Τμήμα Οικονομικών Επιστημών
24	Πανεπιστήμιο Θεσσαλίας, Μονάδα Καινοτομίας και Επιχειρηματικότητας
25	Πανεπιστήμιο Θεσσαλίας, Τμήμα Γεωπονίας Ιχθυολογίας και Υδάτινου Περιβάλλοντος
26	Πανεπιστήμιο Θεσσαλίας, Τμήμα Οικονομικών Επιστημών,
27	Πανεπιστήμιο Θεσσαλίας, Τμήμα Μηχανικών Χωροταξίας, Πολεοδομίας και Περιφερειακής Ανάπτυξης
28	Πανεπιστήμιο Θεσσαλίας, Τμήμα Πολιτικών Μηχανικών
29	Πάντειο Πανεπιστήμιο, Ινστιτούτο Αστικού Περιβάλλοντος και Ανθρώπινου Δυναμικού, Τμήμα Οικονομικής και Περιφερειακής Ανάπτυξης
30	Πανεπιστήμιο Λονδίνου

31	Πανεπιστήμιο Μπέρμιγχαμ, Αγγλία
32	Πανεπιστήμιου του Oulu, Φιλανδία
33	Πανεπιστήμιο Πειραιώς
34	Πανεπιστήμιο Πειραιώς, Τμήμα Χρηματοοικονομικής και Τραπεζικής Διοικητικής
35	Πανεπιστήμιο Politecnica de Valencia, Ισπανία
36	Poyry - Φιλανδία
37	Τεχνολογικό Εκπαιδευτικό Ίδρυμα Αθήνας
38	Τεχνολογικό Εκπαιδευτικό Ίδρυμα Αθήνας, Τμήμα Πληροφορικής,
39	Τεχνολογικό Εκπαιδευτικό Ίδρυμα Δυτικής Μακεδονίας
40	Τεχνολογικό Εκπαιδευτικό Ίδρυμα Πειραιά, Γενικό Τμήμα Μαθηματικών,
41	Χαροκόπειο Πανεπιστήμιο

Συμμετέχοντες Ακαδημαϊκοί - Ερευνητές		
Α/Α	**ΟΝΟΜΑΤΕΠΩΝΥΜΟ**	**ΠΑΝΕΠΙΣΤΗΜΙΟ/ΦΟΡΕΑΣ**
1	Alaaho Pertti	University of Oulu, Φιλανδία
2	Αγγελάκογλου Κομνηνός	Δημοκρίτειο Πανεπιστήμιο Θράκης
3	Ανδρεάδης Όλυμπος	Πανεπιστήμιο Αιγαίου
4	Ανδρεόπουλος Ανδρέας	METIS Accredited Observer to UNFCCC
5	Αντύπας Αντώνιος	Πανεπιστήμιο Πειραιώς
6	Αρβανιτίδης Πασχάλης	Πανεπιστήμιο Θεσσαλίας
7	Βαρσαμούδη Παναγιώτα	Πανεπιστήμιο Θεσσαλίας
8	Βαφείδης Δημήτριος	Πανεπιστήμιο Θεσσαλίας
9	Βελεγράκης Αντώνιος	Πανεπιστήμιο Αιγαίου
10	Clark R.A. Julian	University of Birmingham
11	Γαλάνης Αθανάσιος	Πανεπιστήμιο Θεσσαλίας
12	Γαλάνη Γεωργία	Πανεπιστήμιο Θεσσαλίας
13	Γεωργατζή Βασιλική	Πανεπιστήμιο Θεσσαλίας
14	Γιαννακόπουλος Αθανάσιος	Οικονομικό Πανεπιστήμιο Αθηνών
15	Γκαϊντατζής Γεώργιος	Δημοκρίτειο Πανεπιστήμιο Θράκης
16	Dávila G. Osiel	University of London
17	Δαμίγος Δημήτριος	Εθνικό Μετσόβιο Πολυτεχνείο
18	Δακτυλα Μαρία	Δημοκρίτειο Πανεπιστήμιο Θράκης
19	Δάλλας Νικόλαος	Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης
20	Διακουλάκη Δανάη	Εθνικό Μετσόβιο Πολυτεχνείο
21	Eskelinen Riku	University of Oulu, Φιλανδία
22	Ελευθεριάδης Κων/νος	ΕΚΕΦΕ Δημόκριτος
23	Εξαδάκτυλος Αθανάσιος	Πανεπιστήμιο Θεσσαλίας
24	Ευαγγελινός Κων/νος	Πανεπιστήμιο Αιγαίου
25	Jones Nikoleta	Open University
26	Ηλιού Νικόλαος	Πανεπιστήμιο Θεσσαλίας
27	Karjalainen P Timo	University of Oulu, Φιλανδία
28	Klove Bjorn	University of Oulu, Φιλανδία
29	Καζαμίας Παναγιώτης	Εθνικό Μετσόβιο Πολυτεχνείο,
30	Καλημέρης Παναγιώτης	Πάντειο Πανεπιστήμιο

31	Καμπάς Αθανάσιος	Γεωπονικό Πανεπιστήμιο Αθηνών
32	Κάπρος Παντελής	Εθνικό Μετσόβιο Πολυτεχνείο
33	Καρκατσούλης Παναγιώτης	Εθνικό Μετσόβιο Πολυτεχνείο
34	Κασσιός Κων/νος	Εθνικό Μετσόβιο Πολυτεχνείο
35	Κατρακυλίδης Κων/νος	Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης
36	Κεβόρκ Ηλίας	Πανεπιστήμιο Θεσσαλίας
37	Κίτσος Χρήστος	ΤΕΙ Αθηνών
38	Κίτσου Δήμητρα	Πανεπιστήμιο Θεσσαλίας
39	Κοντογιάννη Αρετή	Πανεπιστήμιο Δυτικής Μακεδονίας
40	Κοπίδου Δήμητρα	Εθνικό Μετσόβιο Πολυτεχνείο
41	Κόλλιας Χρήστος	Πανεπιστήμιο Θεσσαλίας
42	Κουγέα Εύα	Οικονομικό Πανεπιστήμιο Αθηνών
43	Κουρτσίδης Σταύρος	Πανεπιστήμιο Θεσσαλίας
44	Κουντούρη Φοίβη	Οικονομικό Πανεπιστήμιο Αθηνών
45	Κουρογένης Νικόλαος	Πανεπιστήμιο Πειραιώς
46	Κουτσούμπα Κων/να	Γεωπονικό Πανεπιστήμιο Αθηνών
47	Κούγκολος Αθανάσιος	Πανεπιστήμιο Θεσσαλίας
48	Κυρίτσης Ιωάννης	Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης
49	Κωστοπούλου Στέλλα	Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης
50	Κωστάκης Ιωάννης	Χαροκόπειο Πανεπιστήμιο
51	Λοΐζου Ευστράτιος	ΤΕΙ Δυτικής Μακεδονίας
52	Μαλέσιος Χρυσοβαλάντης	Δημοκρίτειο Πανεπιστήμιο Θράκης
53	Μανούση Βασιλική	Οικονομικό Πανεπιστήμιο Αθηνών
54	Μαρκάτου Μαρία	Πανεπιστήμιο Θεσσαλίας
55	Μάρκου Μαρίνος	Ινστιτούτο Γεωργικών Ερευνών, Κύπρος
56	Ματσιώρη Στεριανή	Πανεπιστήμιο Θεσσαλίας
57	Μάττας Κων/νος	Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης
58	Μαυράκη Ελένη-Δανάη	ΚΕΠΑ, ΕΚΠΑ
59	Μαυράκης Δημήτριος	ΚΕΠΑ, ΕΚΠΑ
60	Μεταξάς Θεόδωρος	Πανεπιστήμιο Θεσσαλίας
61	Μιχαηλίδης Αναστάσιος	Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης
62	Μιχαηλίδης Βασίλειος	Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης
63	Μπίθας Κων/νος	Πάντειο Πανεπιστήμιο
64	Μποτζώρης Γεώργιος	Δημοκρίτειο Πανεπιστήμιο Θράκης
65	Νασιώκα Φωτεινή	Πανεπιστήμιο Θεσσαλίας
66	Νάστης Στέφανος	Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης
67	Νεοφύτου Χρήστος	Πανεπιστήμιο Θεσσαλίας
68	Νικολάου Ιωάννης	Δημοκρίτειο Πανεπιστήμιο Θράκης
69	Ξεπαπαδέας Αναστάσιος	Οικονομικό Πανεπιστήμιο Αθηνών
70	Οικονόμου Αθηνά	Πανεπιστήμιο Θεσσαλίας
71	Οικονόμου Γεώργιος	Πανεπιστήμιο Θεσσαλίας
72	Pulido-Velazquez M.	Universitat Politecnica de Valencia, Ισπανία
73	Παιζάνος Επαμεινώνδας	Πανεπιστήμιο Θεσσαλίας
74	Παπαγεωργίου Γεώργιος	Πανεπιστήμιο Θεσσαλίας
75	Παπαδάμου Στέφανος	Πανεπιστήμιο Θεσσαλίας
76	Παπαδοπούλου Μαρία	Εθνικό Μετσόβιο Πολυτεχνείο
77	Παπακωνσταντίνου Δημήτριος	Εθνικό Μετσόβιο Πολυτεχνείο

78	Παρούσος Λεωνίδας	Εθνικό Μετσόβιο Πολυτεχνείο
79	Πάτσικα Βικτωρία	Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης
80	Πολύζος Σεραφείμ	Πανεπιστήμιο Θεσσαλίας
81	Προφυλλίδης Βασίλειος	Δημοκρίτειο Πανεπιστήμιο Θράκης
82	Πρώιας Γεώργιος	Πανεπιστήμιο Θεσσαλίας
83	Reinikainen Kalle	Poyry Φιλανδία
84	Richardson Clive	Πάντειο Πανεπιστήμιο
85	Rossi Pekka Mattias	University of Oulu, Φιλανδία
86	Ράπτης Αθανάσιος	Πανεπιστήμιο Θεσσαλίας
87	Ρίζος Φώτιος	Πανεπιστήμιο Πειραιώς
88	Σαρδιανού Ελένη	Χαροκόπειο Πανεπιστήμιο
89	Σεπετής Αναστάσιος	Γενικό Νοσοκομείο Λαμίας, ΤΕΙ Αθηνών
90	Σκουλούδης Αντώνης	Πανεπιστήμιο Αιγαίου
91	Σκούρτος Μιχάλης	Γεωπονικό Πανεπιστήμιο Αθηνών
92	Σκριμιζέα Ειρήνη	Εθνικό Μετσόβιο Πολυτεχνείο
93	Σοφίου Φραγκίσκη-Ιωάννα	Εθνικό Μετσόβιο Πολυτεχνείο
94	Σταμπουλής Γεώργιος	Πανεπιστήμιο Θεσσαλίας
95	Στήθου Μαύρα	Οικονομικό Πανεπιστήμιο Αθηνών
96	Σταυροπούλου Αθανασία	Χαροκόπειο Πανεπιστήμιο
97	Στεργιάδου Αναστασία	Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης
98	Ταμπέκης Στέργιος	Πανεπιστήμιο Θεσσαλίας
99	Τζερεμές Νικόλαος	Πανεπιστήμιο Θεσσαλίας
100	Τζερεμές Παναγιώτης	Πανεπιστήμιο Θεσσαλίας
101	Τουρκολιάς Χρήστος	Γεωπονικό Πανεπιστήμιο Αθηνών
102	Τσαβδαρίδου Μαρία	Πανεπιστήμιο Θεσσαλίας
103	Τσιλίκα Κορίνα	Πανεπιστήμιο Θεσσαλίας
104	Φλέσσα Άννα	ΚΕΠΑ, ΕΚΠΑ
105	Φράγκος Παναγιώτης	Εθνικό Μετσόβιο Πολυτεχνείο
106	Χάλκος Γεώργιος	Πανεπιστήμιο Θεσσαλίας
107	Zivkovic Marija	ΚΕΠΑ, ΕΚΠΑ