Laboratory of Operations Research
Department of Economics
School of Economics and Business
University of Thessaly

Department of Ichthyology
and Aquatic Environment
School of Agricultural Sciences
University of Thessaly

7th Conference

"Economics of Natural Resources & the Environment"

Friday 26 - Saturday 27 November 2021

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

University of Thessaly – Department of Economics

University of Thessaly - Department of Ichthyology and Aquatic Environment

The Laboratory of Operations Research in the Department of Economics at the University ofThessaly and the Department of Ichthyology and Aquatic Environment at the University of Thessaly organized the 7th Conference "Economics of Natural Resources and the Environment" which was held online on November 26-27th, 2021. The Laboratory of Operations Research organized successfully under the research project COOPERATION 2011 and the project entitled "Greenhouse Gas Emission Scenarios and Policies toCombat them by the year 2030, of Energy, Transport and Industry in Greece" the first two Pan-Hellenic Conferences on the Economics of Natural Resources and the Environment: Climate change on 26-27th March 2014 and October 31st and November 1st , 2014. Then the successful organization of the3rd & 4th Pan-Hellenic Conference on Economics of Natural Resources and the Environment followed, on October 30-31st, 2015 and on November 4-5th, 2016. Continuing this effort, the 5th ENVECONConference was organized on November 1st-3rd, 2018 in the Department of Economics of theUniversity of Thessaly at Volos. While the 6th ENVECON online Conference was organized on June 11-12th, 2021. This year, the 7th ENVECON Conference was held online, due to the COVID-19 pandemic, on November 26-27th, 2021.

This year's conference aimed to present the main issues that concern the Economics of Natural Resources and the Environment and the recent scientific research on the field. The main focus was given on sustainability and effective environmental management, while research on the environmental and social impacts of the recent COVID-19 pandemic will also be presented. The conference aimed to promote the exchange of views and experiences of researchers from different scientific fields and the finding of common components of research approaches, since the environment is governed from interdisciplinarity.
Due to the multidimensional nature of the environment and the interdisciplinarity that is governing the field, the conference covered a lot of the areas associated with the environment, showingonce more the importance of the cooperation of different scientific fields when studying about environmental protection and management.

Conference Scientific

CoordinatorProfessor

George E. Halkos (PhD)

Director of Laboratory of Operations
ResearchDepartment of Economics
School of Economics and
Business University of
Thessaly, Volos, Greece

List of Contents

CONFERENCE COMMITTEES

Scientific Committee

Amman Hans, Professor University of Amsterdam

Apergis Nicholas, Professor, University of Piraeus

Arabatzis Garyfallos, Professor, Democritus University of Thrace

Aravossis Konstantinos, Professor, National Technical University of Athens

Barbier Edward, Professor, Colorado State University

Coccossis Harry, Professor, University of Thessaly

Dasgupta Partha, Sir Professor University of Cambridge

Diakoulaki Danae, Professor, National Technical University of Athens

Filho Leal, Professor, Manchester Metropolitan University

Georgantzis Nikos, Professor, University of Reading

Goeschl Timo, Professor University of Heidelberg

Hatzipanayotou Panos, Professor, Athens University of Economics and Business

Hondroyianis Georgios, Professor, Harokopio University

Hristopoulos Dimitris, Professor, Athens University of Economics

Kagawa Shigemi, Professor, Kyushu University

Kinzig Ann, Professor, Arizona State University

Kitsos Christos, Professor, Technological Educational Institute of Athens

Kollias Christos, Professor, University of Thessaly

Kougolos Athanasios, Professor, Aristotle University of Thessaloniki

Koundouri Phoebe, Professor, Athens University of Economics and Business

Leitão Nuno Carlos, Professor, Polytechnic Institute of Santarém

Löschel Andreas, Professor University of Münster

Markandya Anil, Distinguished Ikerbasque Professor & Former Scientific Director, Basque Centre for Climate Change

Managi Shunsuke, Professor, Kyushu University

Matthopoulos Demetrios, Professor, University of Patras

Mattas Konstantinos, Professor, Aristotle University of Thessaloniki

Mavrakis Dimitrios, Proffessor, National and Kapodistrian University of Athens

Mazzanti Massimiliano, Professor Università di Ferrara

Michalakakou Panagiota, Professor, University of Patras

Mitoula Roido, Professor, Harokopio University

Mpithas Konstantinos, Professor, Panteion University

Oueslati Walid, Professor, Organisation of Economic Cooperation and Development (OECD)

Papandreou Andreas, Professor, National and Kapodistrian University of Athens

Perrings Charles, Professor, Arizona State University

Profillidis Vasilios, Professor, Democritus University of Thrace

Protopapas Angelos, Professor, Democritus University of Thrace

Sartzetakis Eftichios, Professor, University of Macedonia

Skanavis Constantina, Professor, University of the Aegean

Skourtos Michail, Professor, University of the Aegean

Song Malin, Professor, Anhui University of Finance and Economics

Stengos Thanasis Professor, University of Guelph

Stern David, Professor, Crawford School of Public Policy

Tsekouras Kostas, Professor, University of Patras

Tsionas Efthimios, Professor, Athens University of Economics and Business

Vafidis Dimitrios, Professor, University of Thessaly

Wilson Clevo, Professor, Queensland University of Technology

Xepapadeas Anastasios, Professor, Athens University of Economics and Business

Yannacopoulos Athanasios, Professor, Athens University of Economics and Business

Zerefos Christos, Professor, President elect of the International Ozone Commission (IO3C) of IAMAS of ICSU

Zouboulakis Michel, Professor, University of Thessaly

Balsalobre-lorente Daniel , Associate Professor, University of Castilla-La Mancha, Spain

Evangelinos Konstantinos, Associate Professor, University of the Aegean

Exadactylos Athanasios, Associate Professor, University of Thessaly

Kontogianni Areti, Associate Professor, University of Western Macedonia

Koutroympas Konstantina, Associate Professor Harokopio University

Månsson Jonas Associate Professor, Linnaeus University, Sweden

Matsiori Stergiani, Associate Professor, University of Thessaly

Nikolaou Ioannis, Associate Professor, Democritus University of Thrace

Sardianou Eleni, Associate Professor, Harokopio University

Bampatsou Christina, Assistant Professor, Ionian University

Burgess Barbier Jo, Assistant Professor, Colorado State University

Dagoumas Athanasios, Assistant Professor, University of Piraeus

Economou Athina, Assistant Professor, University of Thessaly

Driha Oana, Assistant Professor, University of Alicante, Alicante

Trung Thanh Nguyen, Assistant Professor, Leibniz University Hannover, Germany

Oliveira Amílcar, Assistant Professor, University of Lisbon.

Oliveira Teresa, Assistant Professor, University of Lisbon.

Psarianos Iacovos, Assistant Professor, University of Thessaly

Ren Jingzheng, Asst Professor Hong Kong Polytechnic University

Skouloudis Antonis, Assistant Professor, University of the Aegean

Tsilika Kyriaki, Assistant Professor, University of Thessaly

Papageorgiou George, Dr Senior Researcher, Laboratory of Operations Research, University of Thessaly

Organizing Committee

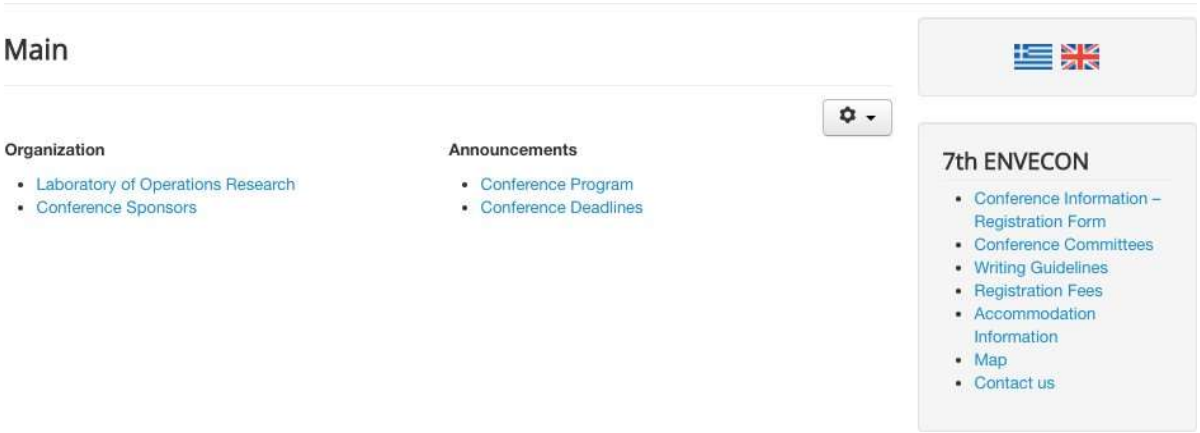
- Sophoklis Dritsas, University of Thessaly (PhD)
- Katsaros Georgios, University of Thessaly
- Gkargkavouzi Anastasia, University of Thessaly (PhD)
- Argyropoulou Georgia, University of Thessaly
- Gkampoura Eleni-Christina, University of Thessaly
- Halkos Emmanouel, University of Patras
- Papageorgiou Ioannis, University of Macedonia
- Tzanetatou Evangelia, University of Brighton
- Tzounas Christos, University of Patras

Technical Support

- Iatridis Alexandros, University of Thessaly
- Katsaros Georgios, University of Thessaly

Conference Website

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



Concise Conference Schedule		
Day	**Time** (Greek Time)	**Sessions-Topics**
Friday 26/11/2021	**09:15-09:45**	**OPENING – WELCOME**
	09:45-11:15	**Session 1:** **Energy Issues & Policies**
	11:15-12:00	**Keynote Speaker** *Professor* Nikos Georgantzis
	12:00-13:45	**Session 2:** **Environment and the Economy**
	13:45-14:15	Break
	14:15-15:00	**Keynote Speaker** *Dr Nikoleta Jones*
	15:00-16:30	**Session 3:** **Environmental behaviour and practices**
	16:30-18:00	**Session 4:** **Sustainable Transport**
Saturday 27/11/2021	**09:15-11:15**	**Session 5:** **Environmental Education**
	11:15-12:00	**Keynote Speaker** *Professor Stefanos Paraskevopoulos*
	12:00-13:30	**Session 6:** **Environmental Management and Valuation**
	13:30-14:15	Break
	14:15-15:45	**Session 7:** **Environmental Policies and Assessment**
	15:45-16:30	**Keynote Speaker** *Professor Konstantina Skanavis*
	16:30-18:20	**Session 8:** **Quantitative Methods in Environmental & Resource Economics**
	18:20-18:30	**CLOSING & FINAL GIVEAWAYS**

CONFERENCE SCHEDULE

Friday 26 November 2021

Opening - Welcome 09:15-09:45

Greeting from the Rector of University of Thessaly Prof. Zissis Mamouris
Greeting from the Dean of the School of Agricultural Sciences, Prof. Nikolaos Danalatos
Greeting from the Dean of the School of Economics and Business, Prof. Christos Kollias
Greeting from the Head of the Department of Ichthyology & Aquatic Environment, Prof. Dimitrios Vafidis
Greeting from the Head of the Department of Economics, Prof. Hlias Kevork

Welcome from the Director of Interdepartmental Postgraduate Studies Program Education for Sustainability and the Environment Associate Professor Steriani Matsiori

1st Session 09:45-11:15

Topic: **Energy Issues and Policies**

Chairperson: **Professor George Halkos**

09:45-10:05	*Energy poverty in rural areas in Greece* Giorgos Giannopoulos, Sofia-Natalia Boemi & Argyro Dimoudi
10:05-10:25	*Household energy poverty: Evidence from Greek households during COVID-19 pandemic* Ioannis Kostakis & Eleni Sardianou
10:25-10:45	*Coping with Energy Poverty* George E.Halkos & Eleni-Christina Gkampoura
10:45-11:05	*How has COVID-19 Impacted Electricity Production Tendencies? An Environmental Investigation of Germany, France, and Italy* Farhang Raymand & Dimitrios Papadopoulos
11:05-11:15	Discussion

Keynote Speaker **11:15-12:00**

Topic: "Environmental innovation and firm profitability"
Professor Nikos Georgantzis
Burgundy School of Business, Dijon France

2nd Session **12:00-13:45**

Topic:	**Environment and the Economy**
Chairperson:	**Assistant Professor Kyriaki Tsilika**
12:00-12:20	*Climate reporting in EU: from NFRD to CSRD and beyond. Implications for Greece* Benjamin Karatzoglou
12:20-12:40	*Sustainable banking practices and customer satisfaction: Empirical evidence from Generation Y* Athanasia Stauropoulou, Eleni Sardianou, Georgios Malindretos, Konstantinos Evangelinos & Ioannis Nikolaou
12:40-13:00	*The socioeconomic and environmental impact of exploration and exploitation of hydrocarbons in maritime areas and the case of Greece* Andreas Stergiou
13:00-13:20	*Uncertainty effects and environmental determinants of Bitcoin's price crash risk during the COVID-19 pandemic* Nikolaos A. Kyriazis
13:20-13:40	*Strategic spatial planning for optimal deployment of fire resources for the protection of natural and built environment from wildfires in the light of climate change* Stavros Sakellariou, Olga Christopoulou & Sophoclis Dritsas
13:40-13:45	Discussion

Keynote Speaker **14:15-15:00**

Topic: "The new EU Biodiversity strategy: Opportunities and socio-economic challenges"
Dr Nikoleta Jones
Associate Professor Institute for Global Sustainable Development
University of Warwick, UK
Deputy Director at Institute for Global Sustainable Development
Director of Research for the School for Cross-Faculty Studies

3rd Session **15:00-16:30**

Topic:	**Environmental Behavior and Practices**
Chairperson:	**Associate Professor Konstantinos Evangelinos**
15:00-15:20	*Consumer perceptions for bioplastics: Notes from the field* Antonios Skouloudis & Altani Panagiotopoulou
15:20-15:40	*Consumer preferences for bio-based products: Preliminary findings from an ongoing investigation* Antonios Skouloudis, Altani Panagiotopoulou & Chrisovalantis Malesios
15:40-16:00	*Workplace human rights assessment in sustainability reports: An overview of the United Kingdom market* Stefanos Fotiadis & Konstantinos Evangelinos
16:00-16:20	*Honeybee Pollination Services: Challenges and Opportunities for Beekeepers and Farmers in Greece* Simeon Marnasidis, Garyfallos Arabatzis, Fani Hatjina, Chrisovalantis Malesios & Efstathia Verikouki
16:20-16:30	Discussion

4th Session **16:30-18:00**

Topic:	**Sustainable Transport**
Chairperson:	**Professor Vasilios Profillidis**
16:30-16:50	*Investigation of changes in the transport habits in Greece due to COVID-19 pandemic* Athanasios Galanis, Dimitra Tsiantoula, Nikiforos Botzoris, Vassilios Profillidis & Panagiotis Lemonakis
16:50-17:10	*Mega Infrastructure Projects and their contribution to Sustainable Development. The case study of the Athens Airport, Eleftherios Venizelos* Roido Mitoula & Angelos Papavasileiou
17:10-17:30	*Driver distraction of cyclists in urban environment: A methodological approach* Dimitrios Kontos, Panagiotis Lemonakis, George Botzonis, Athanasios Galanis & Nikolaos Eliou
17:30-17:50	*New Trans-Arctic shipping routes: Opportunities and challenges for shipping and maritime transport* Joniada Tahiraj & Antonios Skouloudis
17:50-18:00	*Discussion*

Saturday 27 November 2021

5th Session **09:15-11:15**

Topic: **Environmental Education**

Chairperson: **Associate Professor Steriani Matsiori**

09:15-09:35	*Environmental Literacy and Climate Change Perceptions of Primary School Teachers* Chrysovalantis Kalessopoulos, Anastasia Gkargkavouzi & Steriani Matsiori
09:35-09:55	*Energy literacy assessment of Greek secondary students* Konstantinos Kougias, Eleni Sardianou, Anna Saiti & Konstantinos Tsagarakis
9:55-10:15	*Environmental education and sustainability* Ioanna Grigoriadou, Ourania Gkouna & Georgios Tsekouropoulos
10:15-10:35	*Effective educational units: Perceptions & Attitudes of the teachers of public primary schools of the Prefecture of Thessaloniki* Eleni Vlachoudi, Georgios Tsekouropoulos & Nikolaos Katsonis
10:35-10:55	*Educate environmentally conscious teenagers through music and movement* Vasiliki Tsekouropoulou, Vasileios Kasmeris & Eleni Tsompanaki
10:55-11:15	Discussion

Keynote Speaker **11:15-12:00**

Topic: "From environmental education to Education for Sustainable Development"
Professor Stefanos Paraskevopoulos
Department of Special Education, School of Humanities, University of Thessaly
Vice Rector of Administrative Affairs

6th Session **12:00-13:30**

Topic:	**Environmental Management and Valuation**
Chairperson:	**Assistant Professor Antonis Skouloudis**
12:00-12:20	*Economic valuation of «Prepaid Bag – Pay As You Throw (PAYT) System» and «Rewarding Recycling Program»: Case Study of the Municipality of Kozani* Theodoros Adamidis & Dionysis Latinopoulos
12:20-12:40	*Ground management and environmental impact* Ourania Eftychiadou
12:40-13:00	*Precision Forestry Prospects in Greece* Christiana Koliouska
13:00-13:20	*Corporate Social Responsibility, Sustainability Reporting and Forest Fires: Evidence from the 2018 Megafires* Eleni Stathi & Konstantinos G. Papaspyropoulos
13:20-13:30	Discussion

7th Session **14:15-15:45**

Topic:	**Environmental Policies and Assessment**
Chairperson:	**Professor Roido Mitoula**
14:15-14:35	*National budget and environmental subsidies: Optimal management and a dynamic game* George E. Halkos, George J. Papageorgiou, Emmanouil G. Halkos & John G. Papageorgiou
14:35-14:55	*The alignment of Greece with the Environmental Law of the EU: Historical development, current trends and critical implications* Georgios A. Moutsinas, Georgios Meletiadis, Dimitrios S. Prampromis, Zoi Patetsou, Konstantinos D. Patitsas & Sophoklis E. Dritsas
14:55-15:15	*Environmental taxes and their use in European Union* Stavros Tsiantikoudis, Spyros Galatsidas, Anastasia Paschalidou, Eleni Zafeiriou, Garyfallos Arabatzis
15:15-15:35	*Aspects of environmental policies in Athens during the Classical period under an economics perspective* George Halkos, Emmanouil Marios Economou & Nickolaos Kyriazis
15:35-15:45	Discussion

Keynote Speaker **15:45-16:30**

Topic: ""Ecotherapy" with a University prescription"
Professor Constantina Skanavis
Head, Research Unit of Environmental Education and Communication
Laboratory of Hygiene and Epidemiology
Vice Chair, Department of Public and Community Health, University of West Attica

8th Session **16:30-18:20**

Topic: **Quantitative Methods in Environmental & Resource Economics**

Chairperson: **Professor George Halkos**

16:30-16:50	*Spillovers, Technological Hierarchies, and the environmental effects through clean technologies adoption* Nikos Chatzistamoulou, Kostas Kounetas
16:50-17:10	*Two stage DEA and environmental elasticities of polluting DMU's* George Halkos & Christina Bampatsou
17:10-17:30	*A multi-criteria methodology for off-grid small settlements* Evangelos Tsiaras & Frank A. Coutelieris
17:30-17:50	*Testing causalities within the Eurozone economic space at the interface of energy and tourism* George Ekonomou
17:50-18:10	*Use of indexes in evaluating environmental and health efficiency* George Halkos & Georgia Argyropoulou
18:10-18:20	Discussion

Closing **18:20-18:30**

Topic: Closing & Giveaways
Professor George Halkos
Department of Economics, School of Humanities and Social Sciences, University of Thessaly

CONFERENCE PROCEEDINGS

Proceedings Summary

The 7th Conference program consisted of 8 sessions and 4 Keynote speakers. The 8 thematic sessions presented concerned energy issues and policies, environment and the economy, environmental behavior and practices, sustainable transport, environmental education, environmental management and valuation, environmental polices and assessment and quantitative methods in environmental and resource economics. In total, 16 studies were included in the conference proceedings, however, a number of papers has not been included in the book of proceedings since they have already been submitted to the conference special issues journals.

The 1st work by Raymand and Papadopoulos investigates the impact of the COVID-19's timeline to the electricity consumption and emission number in the EU's top three energy producers, Germany, France and Italy, concluding that as the vaccination programs are carried out in each country and nations go through a "reopening phase", the electricity market as well as pollution levels have re-stabilized, nevertheless at a lower level compared to the same time in past years.

The 2nd work by Stergiou takes stock of some characteristic examples of extraction and monetization of hydrocarbons discovered in the sea, identifies major trends and tries to project to the specific circumstances that prevail in Greece. The 3rd work by Sakellariou, Christopoulou and Dritsas focuses on the establishment of optimal location options for initial attack based on burn probability as well as on population capacity. The proposed Spatial Decision Support System would significantly enhance the fire agency's capabilities taking into account the maximization of environmental protection and the rationalization of financial resources.

The 4th work by Skouloudis, Panagiotopoulou, Chrysovalantis and Lekkas explores consumer reactions to bioplastic products. Findings reveal that interviewers have a positive attitude towards bio-based materials with certain issues around the intrinsic characteristics of these products. The 5th work by Skouloudis, Panagiotopoulou and Lekkas examines consumer preferences for bio-based products. Findings indicate that individuals' attributes may influence willingness to pay more for the three bio-based products included in the study (bio-nylon jacket, a pack of bio-based breadsticks, bioplastic bottled water). The 6th work by Marnasidis, Arabatzis, Hatjina, Malesios and Verikouki explores the possibility of providing organized honeybee pollination services in Greece, a country where such services are hardly developed. According to the research, despite the problems, 84.8% of beekeepers and 74.7% of farmers are positive to the participation in a subsidized agri-environmental program for pollination.

The 7th work by Galanis, Tsiantoula, Botzoris, Profilidis and Lemonakis examines the possible changes in the transport habits of citizens in Greece, due to the imposition of measures to prevent and limit the contagion of the Covid-19 pandemic, through a questionnaire survey with 755 participants. The results of this research mainly indicate that the respondents used primarily and secondarily their cars, both before and during the pandemic. In addition, there was a significant reduction in their trips during the period of restrictive measures, the use of public transport was significantly reduced and at the end of the pandemic they will choose to walk for their recreational trips. The 8th work by Papavasileiou and Mitoula investigates as a case study the impact of Eleftherios Venizelos Airport on the sustainable development of the wider host region and its contribution to the national economy and development, confirming the positive contribution of airports to the economic development of a place. The 9th work by Kontos,

Lemonakis, Botzonis, Galanis and Eliou aims to the understanding of the phenomenon of driver distraction and exporting of results, important for the progress in dealing with the phenomenon by the various agencies that can be used as a basis for further research. Findings showed that the phenomenon of driver distraction is real and is a high-risk factor.

The 10th work by Vlachoudi, Tsekouropoulos and Nikolaos highlights the factors that can affect the effectiveness of a school unit and investigates the relationship between these factors, confirming a strong positive linear relationship between the factors that can increase school effectiveness.

The 11th work by Adamidis and Latinopoulos provides estimates, through a questionnaire survey, of: (a) the Willingness to Pay (WTP) for a «Prepaid Bag - Pay As You Throw (PAYT) System», as well as (b) the Willingness to Accept (WTA) for a «Rewarding Recycling Program» respectively, in order to measure the value that the citizens of the Municipality of Kozani attribute to improving the solid waste management system and identify the socio - economic determinants influencing their WTP values. The 12th work by Eftychiadou analyses the positive or negative effects on the environment from the way of the land management. The 13th work by Stathi and Papaspyropoulos explores the way that the top Greek and Californian corporations responded to the 2018 megafires, of Mati, Attica and Camp Fire, California. Based on Corporate Social Responsibility and natural disaster literature, and with the empirical data that were collected, the current research shows A) an important movement from both the Greek and Californian corporations towards the disaster relief efforts, B) the existence of different Corporate Social Responsibility patterns between the two regions and C) an extensive use of sustainability reporting of the Corporate Social Responsibility performers.

The 14th work by George E. Halkos, George J. Papageorgiou, Emmanouil G. Halkos and John G. Papageorgiou examines first the intertemporal optimal management of subsidies offered by the environmental regulator and second the dynamic conflict between two groups of economic agents involved in environmental quality. The 15th work by Halkos, Economou and Kyriazis presents a series of environmental policies that were implemented in the city-state of Athens during the Classical period (508-323 BCE) under an economics perspective by linking these environmental policies to the provision of public goods and with the argument that such goods proved to have been beneficial for the Athenian society as a whole.

The 16th work by Tsiaras and Coutelieris presents a multi-criteria methodology for identifying the most appropriate location(s) for installing low-scale RES-based hybrid electricity production systems to cover local energy demands without grid connection. The 17th work by Halkos and Argyropoulou uses two different Data Envelopment Analysis (DEA) models and two indexes in order to evaluate the efficiency of pollutant management at the expense of health.

As a conclusion, I would like to mention that in this conference we also had interesting presentations and in-depth discussions both by the invited speakers and by the participating academics and researchers. The publication of these practices is based on the responsibility of the research teams and any mistakes, omissions, ambiguities and any similarities with other scientific work are the responsibility of the authors alone.

George E. Halkos
Scientific Coordinator of the Conference
Professor of Natural Resources
Economics Director of Laboratory of
Operations Research

Conference Papers

Energy poverty in rural areas in Greece

Giorgos Giannopoulos, Sofia-Natalia Boemi & Argyro Dimoudi
Laboratory of Environmental and Energy Design of Buildings and Settlements, Department of Environmental Engineering, Democritus University of Thrace, Xanthi
nboemi@gmail.com, adimoudi@env.duth.gr

Abstract
More than a quarter of a century since Boardman's (1991) seminal book on fuel poverty, the concept of energy or fuel poverty has attracted as much attention as ever. It now has a prominent representation in academic literature and the policy seeking to mitigate poverty.
Energy poverty is usually expressed as a condition where households cannot afford to adequately heat or cool homes due to low-income levels or, more broadly, as the inability to attain a socially and materially necessitated level of domestic energy services. In the context of developed countries, energy poverty research has focused on the problem of inadequate leaving conditions and energy accessibility and affordability.
The paper presents research about energy use issues, including energy access and quality, expenditure concerning income, built environment-related aspects and thermal comfort levels in the region of Pieria in Greece. The sampling data are from in-situ audit interviews with a structured questionnaire.
The results showed an inability to adequate heating during winter that is not associated with income but mainly with the heating system and the occupation. Finally, research showed that economic instability affected mainly the middle class. Therefore, measures in favor of energy efficiency aiming to increase households' purchasing power must be at the national level.

Keywords: Energy poverty, Greece, qualitative data analysis

JEL Codes: P18; P4; Q4.

Household energy poverty: Evidence from Greek households during COVID-19 pandemic

Ioannis Kostakis & Eleni Sardianou
Department of Economics and Sustainable Development, School of Environment, Geography and
Applied Economics, Harokopio University, El. Venizelou 70, 17671 Athens, Greece
ikostakis@hua.gr, esardianou@hua.gr

Abstract
The COVID-19 health crisis has led states to redefine their goals and prioritize citizens' health over economic policies. The curfew imposed to control the pandemic has created multiple financial problems. People adapted their daily life and way of life to the new conditions. These included, among other things, a reduction in the income of many workers combined with a reduction in travel and an increase in teleworking from home. Thus the needs of consumers for energy consumption inside the home increased significantly due to their stay at home. This study studies the inability of households to meet their needs and obligations regarding energy consumption within their home. The research was conducted electronically with the participation of a sample of Attica residents during the first phase of the pandemic (April-June 2020). The sample consisted of a total of 850 households that were asked to answer for the cost they paid for energy before and after the pandemic as well as if they were unable to meet their energy needs. Econometric models were evaluated for the purposes of the research. According to the results, household energy costs increased during the pandemic and the percentage of households classified as energy poor is increased. The econometric results suggest that the factors that affect his energy ability are, among other things, telework time, the number of family members and household income. Households have expressed a willingness to develop energy-saving actions, or to change energy lanes due to the increased needs of family members for energy consumption.

Keywords: Energy poverty, Households, COVID-19 pandemic, Regression models

JEL Codes: Q40; Q59; D19; Q56.

Coping with Energy Poverty

George E. Halkos & Eleni-Christina Gkampoura
Department of Economics, University of Thessaly
halkos@econ.uth.gr, egkampoura@uth.gr

Abstract
Energy is an important factor of socioeconomic development and is essential for the satisfaction of basic human needs. Access to energy should be ensured for everyone in the world in order to promote people's welfare. Energy poverty usually refers to a situation where people cannot keep their homes adequately warm, but it is a complex issue with a multi-dimensional nature and many more aspects. This paper presents a review of the energy poverty problem, presenting various definitions given in the literature, identifying the impacts of the problem as well as the drivers that can worsen energy poverty conditions in general. In addition, the Sustainable Development Goals that are linked directly and indirectly with the problem of energy poverty are analyzed. The situation occurring in Europe is also examined: energy poverty is measured for 28 European countries and for the time-period 2004-2019, using a composite measurement and highlighting the countries with the highest and lowest levels of energy poverty, while various drivers of the problem are identified through an econometric analysis. The paper also discusses the different solutions that can help address and tackle the energy poverty problem.

Keywords: Energy poverty, Impacts, Affordability, Sustainable Development Goals, Europe.

JEL Codes: O13; Q01; Q4; Q56.

1. Introduction

Human existence and prosperity rely significantly on every known form of energy (Smil, 1994). Energy use is found in the core of almost every daily activity that largely comprise the areas of mobility, communications, health, and food security. Basic human needs require energy to be accomplished; energy use is therefore important for economic and social development and welfare (Owusu & Asumadu-Sarkodie, 2016). In a household, energy is required for space heating, air-conditioning, water heating, lighting and for the operation of devices, such as refrigerators, cooking appliances, washers and dryers, televisions and electronics, with space heating requiring the most amount of energy among these (EIA, 2020).

Energy poverty, often mentioned as fuel poverty, refers to every energy-related aspect of poverty. Since the definition of poverty is not simple and easy to determine, energy poverty is also difficult to define and conceptualize (Sovacool, 2012). Most of the definitions provided in the literature mainly define energy poverty as the inability to keep a household adequately warm, but energy poverty is a much more complex and multidimensional concept.

After reviewing various energy poverty definitions in the literature, it is observed that they include the concept of access to energy services and/or adequate heating, which can be considered as the core of energy/fuel poverty, although some of them are more inclusive, since they seem to incorporate additional dimensions of the problem, taking into consideration its complexity. These dimensions include, among others, the ability to meet basic or domestic needs (González-Eguino, 2015; Scarpellini et al., 2019), achieve certain activities in the household (Modi et al., 2005) or support human development (Reddy, 2000).

This paper's aim lies mainly on the in-depth examination of the existent literature that focuses on the issue of energy poverty, in order to increase knowledge on the problem and assist in its mitigation, by understanding its drivers and impacts, the ways it can be measured and how it can be tackled. In addition, this paper explores the linkages of energy poverty with the 17 Sustainable Development Goals, while it briefly presents the results of a study on the effect of economic crisis on energy poverty conditions in Europe.

2. Drivers and Impacts of Energy Poverty

Energy poverty can significantly impact various aspects of everyday life and lead to unmet basic needs (Casillas & Kammen, 2010). An energy-poor household, which is not adequately warm, can lead to severe health problems, including: asthma, heart diseases and strokes, increased need for hospitalization or surgery (Thomson & Snell, 2013), respiratory and lung disease or even premature deaths (Kaygusuz, 2011), morbidity and mortality due to indoor air pollution (Sovacool et al., 2012) and illnesses and health problems due to lack of water treatment and purification (García Ochoa & Graizbord, 2016). In addition, energy poverty can have various socioeconomic impacts, since these conditions affect economic development in the short run and the long run (Amin et al., 2020), lower the productivity in the agricultural sector, leading to lower development (González-Eguino, 2015), prevent poverty eradiation and socioeconomic progress (Vera et al., 2005; Acharya & Sadath, 2019) and produce negative impacts on children's education and learning progress (Kanagawa & Nakata, 2006).

Energy poverty could be a result of various socioeconomic and environmental factors, while specific household characteristics can also have a significant influence. The household characteristics that could be viewed as energy poverty drivers include: household's income (Trinomics, 2016; Bollino & Botti, 2017), household's location (Thomson & Snell, 2013), energy inefficient household (Thomson & Snell, 2013; European Commission, 2014), number of rooms (Thomson & Snell, 2013), insufficient information (European Commission, 2014). The socioeconomic factors that could be viewed as energy poverty drivers include: economic and

political systems (Bouzarovski et al., 2012; Thomson & Snell, 2013), energy market system (Trinomics, 2016), energy/electricity prices (Halkos & Gkampoura, 2021; European Commission, 2014; IEA, 2020), state of the economy (i.e. economic crisis) (Trinomics, 2016; Halkos & Gkampoura, 2021). Additionally, the environmental factors that could be considered energy poverty drivers include climate conditions (Trinomics, 2016) and climate change (Sumiya, 2016).

3. Energy Poverty and SDGs

The issue of energy poverty is linked with most of the 17 Sustainable Development Goals, that the United Nations introduced in 2015, aiming to tackle various economic, social and environmental issues and promote the concept of sustainability (United Nations, 2015). More specifically, energy poverty is directly linked with the 7th SDG, that aims to ensure universal access to affordable, reliable, sustainable and modern energy mainly by ensuring that world's population will have access to electricity and to clean fuels and technologies. In addition, it aims to increase the share of renewables in the global energy mix, improve energy efficiency while promoting clean energy research and technologies.

Based on the World Bank database, in 2018, 89.6% of world's population had access to electricity. The lowest percentages were observed in Sub-Saharan Africa, where only 26% of population in 2000 and 47.7% in 2018 had access to electricity. Low percentages were observed in South Asia in the first years of the 21st century although this percentage had witnessed a remarkably increase by 2018 when it reached 91.6%. High percentages of electricity access were noted in every other region in the world (World Bank, 2020).

In addition, after taking into consideration the impacts of energy poverty, it is obvious that the problem is related with some other goals as well, including the 1st SDG (no poverty), the 3rd SDG (good health and well-being), the 4th SDG (quality education), the 10th SDG (reduced inequalities), the 11th SDG (sustainable cities and communities) and the 13th SDG (climate action)*.

4. Measuring Energy Poverty

The main approaches that are proposed and followed in the literature concerning the measurement of energy poverty, are the expenditure approach and the consensual approach. The expenditure approach takes into consideration the household's expenditure on energy, using an expenditure indicator, such as the household's expenditure on energy, its share on income, etc. (Bollino & Botti, 2017). This indicator is often compared to a certain critical threshold, and it is assessed whether a household is energy poor or not, depending on whether its expenditure metric is above or below the threshold (Trinomics, 2016).

In the consensual approach, various measures and metrics are used that can capture the energy situation occurring in a household, such as thermal comfort and adequate warmth, energy affordability, dwelling efficiency, etc. Such metrics can be used as proxies, and they can be combined and evaluated jointly, in order to identify whether a household is energy poor or not. The necessary data used in the consensual approach are collected via surveys; this means that the information provided are subjective assessments that the households perform regarding their energy conditions (Trinomics, 2016).

In addition to the two main approaches used to measure energy poverty, a few more have been proposed in the literature, including a temperature-based approach and an outcome-based approach, however the lack of data and the lack of national statistics and the presence of causality problems makes it difficult to use them for measuring energy poverty (Trinomics, 2016).

5. Energy Poverty in Europe

The consensual approach and a composite measurement have been used to examine energy poverty conditions in 28 European countries for the time-period 2004-2019, in order to evaluate the impact of economic crisis on energy poverty. Three indicators that are provided by the EU-SILC were used: inability to keep home adequately warm, arrears on utility bills and presence of leak, damp, rot in the dwelling. Following Thomson and Snell's (2013) methodology, a different weight was assigned to each one of the three main indicators and 4 different scenarios were created. In addition, these results were evaluated for three different time-periods: 2004-2008 (before the outbreak of the global economic crisis), 2009-2013 (when the effects of the economic crisis were visible in most European countries) and 2014-2019 (when the effects of the economic crisis had faded in most European countries). The results suggest that the lowest levels of energy poverty were found in the Scandinavian countries, while the highest levels were found in Bulgaria. It was also observed that energy poverty levels were higher in the period 2009-2013, compared to the other two studied time-periods.

At the same time, a set of panel data of seven secondary indicators were used, to identify the drivers of energy poverty. A regression analysis was conducted, and static and dynamic models were created, while various econometric tests were also conducted, testing for cross-section dependence, unit roots and cointegration. Based on this analysis, electricity prices were found to be the main driving force of energy poverty, among the studied variables, while unemployment and poverty risk were also drivers of certain energy poverty aspects. In addition, GDP per capita is found to be linked with an inverse relationship to energy poverty, meaning that economic growth can improve such conditions and confirming the fact that the economic crisis actually had a negative impact on energy poverty in Europe*.

6. Tackling Energy Poverty

Energy poverty is a social issue with great influence on people's welfare. It is therefore important to focus on the development of tools and the implementation of policies that aim to eradicate the problem and provide access to modern, affordable, and reliable energy for as many people in the world as possible.

In the literature, various actions are suggested that could help address the problem, including: changes to the living environments (Ürge-Vorsatz & Tirado Herrero, 2012), implementation of new technologies (Obeng et al., 2008; Oldfield, 2011), promotion of energy transition (Bhide & Monroy, 2011), as well as promotion of related polices and legislation (Pye et al., 2015) and financial schemes (Lakatos & Arsenopoulos, 2019).

Energy poverty is not a problem easy to eradicate, and its multidimensional nature makes it more difficult to address it efficiently. It is therefore necessary to implement not only one but a series of different actions, that are targeted to certain areas or regions based on their characteristics, in order to eradicate energy poverty.

7. Conclusions

Energy is vital for good living conditions and people's welfare, since it is required for the achievement of most of the basic everyday-life activities. However, a significant number of people in the world still face energy-related difficulties: approximately 1.1 billion people did not have access to electricity in 2016, while an also notable number of people cannot meet their basic

energy needs. This problem is referred to as energy poverty and is an issue that concerns researchers and policy makers around the world the last decades.

Energy poverty can impact various aspects of everyday life: it can cause severe health problems, affect education and communication, prevent social and economic progress and development, and have a negative environmental impact. Energy poverty can be driven by specific household characteristics, including income, location and energy inefficiency, as well as by socioeconomic and environmental factors, such as political and market systems, energy prices, state of the economy and climate change.

It is therefore obvious that it is an urgent need to undertake a set of actions in order to help eradicate the problem of energy poverty in the long run and to achieve the 7th Sustainable Development Goal that the United Nations have set, ensuring access to affordable, reliable, and modern energy for all by 2030.

**The paper presented at the 7th Conference of Economics of Natural Resources and the Environment is mainly based on the following publication:*

Halkos, G. E., & Gkampoura, E. C. (2021). Coping with Energy Poverty: Measurements, Drivers, Impacts, and Solutions. *Energies*, 14(10), 2807.

In addition, this paper contains parts of the following publications:

Halkos, G. E., & Gkampoura, E. C. (2021). Evaluating the effect of economic crisis on energy poverty in Europe. *Renewable and Sustainable Energy Reviews*, 144, 110981.

Halkos, G., & Gkampoura, E. C. (2021). Where do we stand on the 17 Sustainable Development Goals? An overview on progress. *Economic Analysis and Policy*.

References

Amin, A., Liu, Y., Yu, J., Chandio, A. A., Rasool, S. F., Luo, J., & Zaman, S. (2020). How does energy poverty affect economic development? A panel data analysis of South Asian countries. *Environmental Science and Pollution Research*, 27(25), 31623-31635.

Acharya, R. H., & Sadath, A. C. (2019). Energy poverty and economic development: Household-level evidence from India. *Energy and Buildings*, 183, 785-791.

Bhide, A., & Monroy, C. R. (2011). Energy poverty: A special focus on energy poverty in India and renewable energy technologies. *Renewable and Sustainable Energy Reviews*, 15(2), 1057-1066.

Bollino, C. A., & Botti, F. (2017). Energy poverty in Europe: A multidimensional approach. *PSL Quarterly Review*, 70(283).

Bouzarovski, S., Petrova, S., & Sarlamanov, R. (2012). Energy poverty policies in the EU: A critical perspective. *Energy Policy*, 49, 76-82.

Casillas, C. E., & Kammen, D. M. (2010). The energy-poverty-climate nexus. Science, 330(6008), 1181-1182.

EIA. Use of Energy Explained. Energy Use in Homes. Retrieved from EIA—U.S. Energy Information Administration. Available online: https://www.eia.gov/energyexplained/use-of-energy/homes.php (accessed on 19 October 2020).

European Commission. (2014). Energy Stewards to Reduce Energy Poverty. Retrieved from EU Energy Poverty Observatory. Available online: https://www.energypoverty.eu/news/energy-stewards-reduce-energy-poverty (accessed on 26 October 2020).

García Ochoa, R., & Graizbord, B. (2016). Privation of energy services in Mexican households: An alternative measure of energy poverty. *Energy Research & Social Science*, 18, 36-49.

González-Eguino, M. (2015). Energy poverty: An overview. *Renewable and Sustainable Energy Reviews*, 47, 377-385.

Halkos, G. E., & Gkampoura, E. C. (2021). Evaluating the effect of economic crisis on energy poverty in Europe. *Renewable and Sustainable Energy Reviews*, 144, 110981.

IEA. (2020). Energy Prices 2020. IEA. Paris. Available online: https://www.iea.org/reports/energy-prices-2020 (accessed on 26 October 2020).

Kanagawa, M., & Nakata, T. (2006). Socio-economic impacts of energy poverty alleviation in rural areas of developing countries. In *Proceedings of the 26th USAEE/IAEE North American Conference*, *Ann Arbor, MI, USA* (pp. 24-27).

Kaygusuz, K. (2011). Energy services and energy poverty for sustainable rural development. *Renewable and Sustainable Energy Reviews*, 15(2), 936-947.

Lakatos, E., & Arsenopoulos, A. (2019). Investigating EU financial instruments to tackle energy poverty in households: A SWOT analysis. *Energy Sources, Part B: Economics, Planning, and Policy*, 14(6), 235-253.

Modi, V., McDade, S., Lallement, D., & Saghir, J. (2005). Energy Services for the Millennium Development Goals. Energy Sector Management Assistance Programme, United Nations Development Programme, UN Millennium Project, and World Bank: New York, NY, USA.

Obeng, G. Y., Evers, H. D., Akuffo, F. O., Braimah, I., & Brew-Hammond, A. (2008). Solar photovoltaic electrification and rural energy-poverty in Ghana. *Energy for Sustainable Development*, 12(1), 43-54.

Oldfield, E. (2011). Addressing energy poverty through smarter technology. *Bulletin of Science, Technology & Society*, 31(2), 113-122.

Owusu, P. A., & Asumadu-Sarkodie, S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering*, 3(1), 1167990.

Pye, S., Dobbins, A., Baffert, C., Brajkovic´, J., Grgurev, I., Miglio, R., Deane, P. (2015). Energy Poverty and Vulnerable Consumers in the Energy Sector across the EU: Analysis of Policies and Measures. INSIGHT_E. Retrieved from EU Energy Observatory. Available online: https://www.energypoverty.eu/publication/energy-poverty-and-vulnerable-consumers-energy-sector-across-eu-analysis-policies-and (accessed on 16 October 2020).

Reddy, A.K. (2000). Energy and Social Issues. In *World Energy Assessment: Energy and the Challenge of Sustainability*. Available online: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.196.4978&rep=rep1&type=pdf (accessed on 19 October 2020).

Scarpellini, S., Hernández, M. A. S., Moneva, J. M., Portillo-Tarragona, P., & Rodríguez, M. E. L. (2019). Measurement of spatial socioeconomic impact of energy poverty. *Energy Policy*, 124, 320-331.

Smil, V. (1994). *Energy in world history*. Routledge: Abingdon, UK.

Sovacool, B. K. (2012). The political economy of energy poverty: A review of key challenges. *Energy for Sustainable Development*, 16(3), 272-282.

Sovacool, B. K., Cooper, C., Bazilian, M., Johnson, K., Zoppo, D., Clarke, S., Eidsness, J., Crafton, M., Velumail, T., & Raza, H. A. (2012). What moves and works: Broadening the consideration of energy poverty. *Energy Policy*, 42, 715-719

Sumiya, B. (2016). Energy poverty in context of climate change: What are the possible impacts of improved modern energy access on adaptation capacity of communities?. *International Journal of Environmental Science and Development*, 7(1), 73.

Thomson, H., & Snell, C. (2013). Quantifying the prevalence of fuel poverty across the European Union. *Energy Policy*, 52, 563-572.

Tirado Herrero, S. (2017). Energy poverty indicators: A critical review of methods. *Indoor and Built Environment*, 26(7), 1018-1031.

Trinomics. (2016). Selecting Indicators to Measure Energy Poverty. Available online: https://ec.europa.eu/energy/sites/ener/files/documents/Selecting%20Indicators%20to%20Measure%20Energy%20Poverty.pdf (accessed on 22 October 2020)

Ürge-Vorsatz, D., & Tirado Herrero, S. (2012). Building synergies between climate change mitigation and energy poverty alleviation. *Energy Policy*, 49, 83-90.

United Nations. (2015). The 17 goals. Available online: https://sdgs.un.org/goals (Accessed on November 2nd, 2020).

Vera, I. A., Langlois, L. M., Rogner, H. H., Jalal, A. I., & Toth, F. L. (2005). Indicators for sustainable energy development: An initiative by the International Atomic Energy Agency. In *Natural Resources Forum* (Vol. 29, No. 4, pp. 274-283). Oxford, UK: Blackwell Publishing Ltd.

World Bank. (2020). Access to electricity (% of population). Retrieved from The World Bank Data. Available online: https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS (accessed on November 8th, 2020).

How has COVID-19 Impacted Electricity Production Tendencies? An Environmental Investigation of Germany, France, and Italy

Farhang Raymand & Dimitrios Papadopoulos
Department of Energy, Politecnico di Milano, Piacenza Italy
farhang.raymand@mail.polimi.it, dimitrios.papadopoulos@mail.polimi.it

Abstract
Undoubtedly, the COVID-19 pandemic has caused major issues in education, health systems and economy. This has led to considerable change in trends of consumer behavior everywhere. In this article, we review the implications of the current situation on the energy market. Additionally, many industries went through shutdowns, which in turn has impacted environmental quality. This work considers the electricity profiles of EU's top three energy producers, Germany, France, and Italy. We investigate how the timeline of COVID-19 has impacted the consumption and emission numbers. Supervised machine learning has been used to learn from previous data and predict the daily electricity production in these countries amidst COVID-19. For this process, the most important features are the total cases, the daily cases, the logarithmic of the total cases on 7-day average and the vaccinations. The predictions shows that the model was accurate with R^2 index ≥80%. Furthermore, it is analyzed how different features impact the consumption and to what extent they are correlated amongst themselves. As the vaccination programs are carried out in each country and nations go through a "reopening phase", the electricity market as well as pollution levels have re-stabilized, nevertheless at a lower level compared to the same time in past years.

Keywords: Energy consumption; energy forecast; machine learning; COVID-19.

JEL Classification: O13; P18; P48; Q41; Q47.

1. Introduction

The World Health Organization changed the category of COVID-19 in March 2020 from outbreak to pandemic (WHO, 2020). Governments around the world responded with measures prohibiting movement and traveling, such as curfews and lockdowns in addition to measures that were aiming to reduce overcrowding in workplaces and public transport (Palaniappan et al., 2020). However, these measures had the adverse side effect of slowing down economic development and partially impeded international trade. On the other hand, with the withdrawal of these restrictions, getting the workforce back to production is still arduous due to the ongoing character of the pandemic, therefore creating recession in the economy. This can be seen in changes of GDP in the three major economies of the EU, where in the second quarter of 2020, Italy has seen a reduction of -13.1%, Germany -10% and France -13.5% (Eurostat, 2021).

However, the environmental aspect during the pandemic cannot be left uncommented. During the pandemic, fueled by nation-wide lockdowns, NO2 has been reduced by 5% and PM2.5 has fallen by 4% due to the transportation restrictions, on a global level (Dang and Trinh, 2021). As an instance, in the Lombardy region of Italy, there has been observed the largest decrease of nitrogen dioxide levels (Rovetta, 2021) On the other hand, there has been correlation between the COVID-19 fatalities and particulate matter pollution, in different counties, due to the fact that these particles may carry the virus and moreover increase the severity of respiratory diseases (Prinz and Richter, 2022). Similar methodology was used to study big metropolitan cities in France, e.g. Paris, Lyon and Marseille, suggesting that emissions of the PM10 and PM2.5 type, can increase the lethality of COVID-19 (Magazzino et al., 2020). In addition, temperature can play an important role in the spread of the virus. According to Iqbal et al. (2020) the spreading of the virus and its severity, was found to be faster and more intense, in countries with relatively cooler climatic conditions than in countries with warmer climatic conditions, despite differences in socio-economic conditions.

Machine Learning is a subset of Artificial Intelligence (AI). It is defined as utilizing different algorithms in order to find patterns within data and therefore enabling the computer to predict or optimize performance (Belyadi and Haghighat, 2021). A huge increase has been observed in recent years regarding the amount of data and different types of datasets available to the public. However, extracting useful features and conclusions from these datasets can prove to be tricky, which is why since the 1990s, data mining has become a much-followed topic in the academic field (Mannila, 1996). Ever since the start of the pandemic, most countries have been releasing daily or weekly reports of the number of cases, deaths, vaccinations and so on. This has led to the creation of a substantial dataset over the past two years. Different variants of the COVID-19 pandemic have made it very difficult for policy makers to “take things back to normal”.

In this work, we first took 15-minute consumption data as well as daily Covid-19 data and made a final dataset for the three countries under study. The dataset begins from 2018 and ends in the first week of November, 2021. Then, a feature engineering step was performed, where temporal features such as day of week, month, weekend flag and others were defined and added to the database. Moreover, some statistical features such as the mean logarithm of daily cases were added to the dataset based on the previous experiences. Next, we ran a feature selection algorithm that could tell us which features have the most importance in the final consumption of each country. Finally, a t-pot module optimization of the pipeline was performed and the final optimized pipeline was exported

2. Literature Review

Other researchers have authored multiple papers on different aspects of the covid-19 pandemic whether in policies, effects, suggestions and so on. For the purpose of this work, we will look at some of the work that has considered the impacts of the pandemic in the energy sector.

Many studies have been carried out as case studies of a single nation or city. Being the starting ground for the spread of the virus, China has seen many researchers analyzing different aspects of the country with regards to the pandemic. (Wang and Su, 2020) did a case study of china, where they analyzed the effect of covid-19 lockdowns on the environment. They found that greenhouse gas emissions, specifically NO2 have reduced in the short-term, even though there is no guarantee that when all measures are lifted, these won't go back to, or even exceed their previous levels. In another work, (Wang et al, 2020) concluded that while co2 emissions have been reduced due to the pandemic, in the long run, the need to "catch up" with previous projects, as well as the financial stimulus packages incentivized by the government will lead to even higher levels of emissions. They suggested the introduction of a sustainable stimulus package to promote their climate goals.

In Europe, (García et al, 2021) used the smart meter data from a town in Seville, Spain to evaluate the short term and midterm impact of covid-19 lockdown and the effect of each phase of the crisis on the consumption profile. They also clustered the users into different groups based on usage patterns as well as residential or non-residential grouping.

In Canada, (Abu-rayash and Dincer, 2020) examined the trends in consumption in Ontario, Canada for the month of march 2020, which was the initial lockdown. They Concluded that the consumption profile has differed compared to pre-pandemic recordings. They also used measured data to forecast the usage under different scenarios (in order of stringency of measures) for the next months. (Rouleau and Gosselin, 2021) analyzed a social housing building in Quebec City, Canada and looked at the consumption patterns. They found that during the initial two months, which coincided with the toughest lockdowns, consumption had changed and moreover, the pattern had become flatter and more constant throughout the day.

A number of works have been focused on the Indian consumption and power grid. For instance, (Rajvikram et al , 2020) studied the Indian power grid and the challenges it faced in the face of the pandemic, since the pandemic has led to different behavior shifts in the consumption of the residential and non-residential sectors. (Aruga et al, 2021) looked at the consumption profiles, but also while taking into consideration the socioeconomic conditions of different regions. They analyzed the behavior of each of the regions in the reopening phase and concluded that while as the number of cases increased, the profile of consumption also bounced back to previous levels, in the poorer regions, this recovery was far slower and might even need stimulating aid from the government.

Some have looked at different aspects of the energy sector. For example, (Huang and Tian, 2020) analyzed the effect of covid-19 pandemic on the concept of co2 inequality by assessing 8 developing countries. They concluded that while in short-term, the inequality of CO2 and GHG emissions have been improved, the issue would most likely persist in the long run.

As a result of this vast endeavor to better understand the pandemics' causes and effects, some insight has been found into the correlations between various issues. (Mofijur et al, 2020) looked at the effect of the pandemic on the energy sector and energy products. They also found that a delay in collecting waste from households, led to an increase of the spread of the virus, and came up with a list of suggestions and ideas to move forward.

3. Methods and Data

3.1 Dataframe Creation and Cleaning

First, electricity consumption data for each country was downloaded from the responsible regulatory or transmission authority or the electricity market platform (Smard, 2021; RTE-France, 2021; Terna, 2021). These data were recorded at 15-minute intervals and went back to the year 2018 for the purpose of this research. Covid cases/deaths and vaccination data were obtained from CSSEGISandData (available on John Hopkin university portal at GitHub) and OWID(Our World In Data portal on GitHub) respectively. These data were on a daily basis. In order to fit all the data into one dataset, or dataframe as it is called in the pandas environment of python, consumption data were summed to give the daily values.

Since covid data is nonexistent prior to 2020, these numbers will be shown as NaN in python. These values were all set to zero. Moreover, outlying data points were removed, as they were assumed to have occurred as a result of system error or communication mishaps.

3.2 Feature Engineering

A list of features was defined and added to the dataset. These features could range from temporal like data recordings over a period of time or even details such as day of week and month, to statistical ones such as averages or means. The final list of features that were used in the data frames is presented as follows. The ones with an asterix were generated while the rest were found as they were.

Table 1. List of features

Daily_Consumption	total_boostersper_hundred
Total_Cases	*dayOfWeek
*TotalCases7dayAvg	*month
*TotalCases7dayAverageLogarithmic	*WeekOfYear
Daily_Cases	*week
*DailyCases7dayavg	*weekendFlag
*DailyCases7dayavgerage logarithmic	*WorkingDayFlag
total_vaccinations	*RestDayFlag
people_vaccinated	*Total_Cases@-1d
people_fully_vaccinated	*Total_Cases@-2d
total_boosters daily_vaccinations	*Total_Cases@-3d
total_vaccinationsper_hundred	*Total_Cases@-4d
people_vaccinated_per_hundred	*Total_Cases@-5d
people_fully_vaccinated_per_hundred	*Total_Cases@-6d

The reasoning behind making new features is that these features might be able to explain the phenomenon we study better. For example, the consumption on a Tuesday might be similar to

the previous Tuesday which is why we define a day of week feature. Another temporal feature that may come in handy is the rest day flag, which considers not only the weekends but also holidays in each country.
On the other hand, the number of total cases fluctuates rather heavily from one day to the next, which is why taking a logarithm tends to smooth out these noises. More features can always be thought of and will be added to any following work to dig deeper into the correlations.

3.3 Machine learning and Model Training
Now that the data set is cleaned and has all the features added to it, we can import the sklearn module from python library scikit-learn and utilize different regressors to first train and then evaluate the model against a test subset of the dataset. The dataset needs to be divided into a train and test subset. Here we have taken 90% of the data for the training dataset at random and the remaining 10% will be used for testing the model. Two different regressors were used in this work.
First, linear regression was used to train the algorithm. Then a c-fold cross validation was used to improve upon the results. Cross-validation, sometimes called rotation estimation or out-of-sample testing, is any of various similar model validation techniques for assessing how the results of a statistical analysis will generalize to an independent data set. Cross-validation is a resampling method that uses different portions of the data to test and train a model on different iterations. It is mainly used in settings where the goal is prediction, and one wants to estimate how accurately a predictive model will perform in practice. In a prediction problem, a model is usually given a dataset of known data on which training is run (training dataset), and a dataset of unknown data (or first seen data) against which the model is tested (called the validation dataset or testing set). The goal of cross-validation is to test the model's ability to predict new data that was not used in estimating it, in order to flag problems like overfitting or selection bias and to give an insight on how the model will generalize to an independent dataset (i.e., an unknown dataset, for instance from a real problem).
To reduce variability, in most methods multiple rounds of cross-validation are performed using different partitions, and the validation results are combined (e.g. averaged) over the rounds to give an estimate of the model's predictive performance. (Kohavi, 1995)
As one can assume, the linear regression method is not a very reliable and precise way to train the algorithm, which is why a random forest algorithm is used . Random Forest Regression is a supervised learning algorithm that uses ensemble learning methods for regression. Ensemble learning method is a technique that combines predictions from multiple machine learning algorithms to make a more accurate prediction than a single model. A Random Forest Regression model is powerful and accurate, and that's why the results are extracted from this technique. It usually performs great on many problems, including features with non-linear relationships. Disadvantages, however, include the following: there is no interpretability, overfitting may easily occur, we must choose the number of trees to include in the model.

4. Results

Two important metrics are used to evaluate the performance and accuracy of a model. These are the R^2 score and WAPE (short for Weighted Absolute Percentage Error). A better R^2 score is one that is closer to 1, meaning a linearity between the prediction and the actual data. For the WAPE metric, since it is defined as an error, it should be closer to zero to make for a better model.

Table 2. WAPE and R^2 Scores for Each model

	RF Regression			RF regression for only COVID-19		
	France	**Italy**	**Germany**	**France**	**Italy**	**Germany**
WAPE	8.342	4.23	3.297	5.422	7.035	5.352
R^2	0.561	0.814	0.812	0.842	0.278	0.361

The first point to consider when looking at this table is that even before optimization, the model has been proving to be accurate enough with R^2 scores of over 81%. However, since the model for French data was not performing well, we run the code again, using only the COVID time data and it proved to be much more effective, also scoring over 81% for R^2.

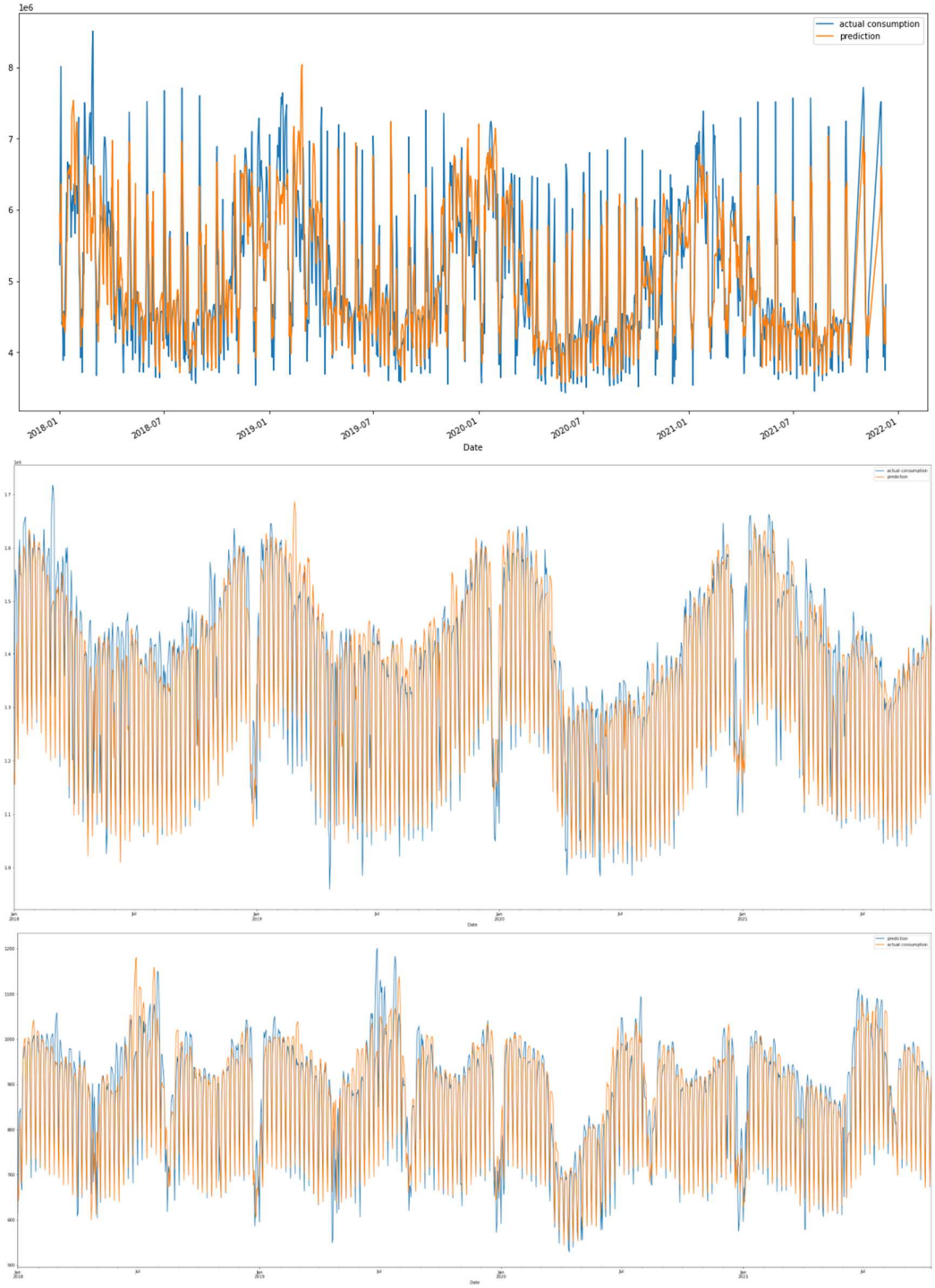


Figure 2: Real vs Prediction Results for France, Germany and Italy respectively

5. Conclusions and discussion

In this study we built a model, which could be used as a policy making tool, to predict the energy demand of a country using already-existing data from the electricity transmission and distribution operators (TSOs and DSOs). In addition to that, we investigated if the power

consumption could be predicted by feeding the model with pandemic data (daily cases, vaccinations etc.). This way we identify if the national policies for fighting COVID-19 had an effect on energy consumption. Furthermore, by testing three different countries we wanted to test the repeatability of the algorithm for a different variety of data and regions.

Considering the data from the whole time period, the model predicted the consumption rather well for Germany and Italy with an R^2 score ≥80%. However, the prediction for France did not perform so well. To counter that, we approached the problem from a different perspective. We trained the algorithm with data, dating from the first COVID-19 infection, leading to results this time that were significantly different. The model, this time, was able to achieve an R^2 score ≥80% for France and outperformed the other two countries. In conclusion, on one hand, predictions for Germany and Italy needed a full range of data to perform well, however on the other hand, the model for France could perform well, considering only the pandemic time series data. This means that, even if all countries were badly influenced by the pandemic, Germany and Italy maintained a level at which their energy consumption curve has been reduced but not completely changed its profile. In comparison, the French power production (and therefore the consumption) has been completely changed during the pandemic due to the fact that the French electricity mix is mainly based on nuclear power. Therefore, after the pandemic struck, there was a lot of rescheduling on planned outages and maintenance for the nuclear power plants to be ready for the upcoming winter period, to support the security of the grid. This further underlines how important is the energy diversification of the electricity mix.

References

Abu-Rayash A. and Dincer I. (2020). Analysis of the electricity demand trends amidst the COVID-19 coronavirus pandemic. Energy Research Social Science, 68, 101682.

Aruga K, Islam M, Jannat A. (2020). Effects of COVID-19 on Indian energy consumption. Sustainability, 12(14), 5616.

Belyadi H and Alireza Haghighat (2021). Machine Learning Guide for Oil and Gas Using Python.

Dang H and Trinh T. (2021). Does the COVID-19 lockdown improve global air quality? New cross-national evidence on its unintended consequences. Journal Environmental Economics and Management.105:102401.

Eurostat (2021). Statistics on the economy related to COVID-19. Available from: https://ec.europa.eu/eurostat/web/covid-19/economy (Accessed: 19/10/2021)

García S, Parejo A, Personal E, Guerrero J. I, Biscarri F, León C. (2021). A retrospective analysis of the impact of the COVID-19 restrictions on energy consumption at a disaggregated level. Applied energy, 287, 116547

Huang, R. and Tian, L. (2021). CO2 emissions inequality through the lens of developing countries. Applied energy, 281, 116043.

Iqbal MM, Abid I, Hussain S, Shahzad N, Waqas MS, Iqbal MJ.(2020). The effects of regional climatic conditions on the spread of COVID-19 at global scale. Sci Total Environ. 739:140101.

Kohavi R. (1995). "A study of cross-validation and bootstrap for accuracy estimation and model selection". Proceedings of the Fourteenth International Joint Conference on Artificial Intelligence. San Mateo, CA: Morgan Kaufmann. 2 (12): 1137–1143. CiteSeerX 10.1.1.48.529

Magazzino C, Mele M, Schneider N. (2020). The relationship between air pollution and COVID-19-related deaths: An application to three French cities. Applied Energy, 279:115835

Mannila H. (1996). "Data mining: machine learning, statistics, and databases," Proceedings of 8th International Conference on Scientific and Statistical Data Base Management, pp. 2-9..

Mofijur M, Fattah I. R, Alam M. A, Islam A. S, Ong H. C., Rahman S. A., Mahlia T. M. I. (2021). Impact of COVID-19 on the social, economic, environmental and energy domains: Lessons learnt from a global pandemic. Sustainable production and consumption, 26, 343-359

Palaniappan A, Dave U, Gosine B. (2020). Comparing South Korea and Italy's healthcare systems and initiatives to combat COVID-19, Rev. Panam. Salud Públic, 44:e53.

Prinz A. L. and Richter D. J. (2022). Long-term exposure to fine particulate matter air pollution: An ecological study of its effect on COVID-19 cases and fatality in Germany, Environmental Research, 204A:111948

Rajvikram M.E, Shafiullah GM., Kannadasan R., Mudgal V., Arif M.T., Taskin J., Subramanian S., Balaguru V.S.S., Reddy K.S., Subramaniam U. (2020). COVID-19: Impact analysis and recommendations for power sector operation, Applied Energy, 279, 115739

Rouleau J. and Gosselin L. (2021). Impacts of the COVID-19 lockdown on energy consumption in a Canadian social housing building. Applied Energy, 287, 116565.

Rovetta A. (2021). The impact of covid-19 lockdowns on particulate matter emissions in Lombardy and Italian citizens' consumption habits. Frontiers in Sustainability.

RTE-France (2021). Market Data. Available from: https://www.services-rte.com/en/download-data-published-by-rte.html (Accessed: 9/11/2021)

Smard (2021). Market Data. Available from: https://www.smard.de/en/downloadcenter/download-market-data#!?downloadAttributes=%7B%22selectedCategory%22:false,%22selectedSubCategory%22:false,%22selectedRegion%22:false,%22from%22:1638658800000,%22to%22:1639609199999,%22selectedFileType%22:false%7D (Accessed: 9/11/2021)

Terna (2021). Market Data. Available from: https://www.terna.it/en/electric-system/transparency-report/download-center (Accessed: 9/11/2021)

Wang Q., Lu, M., Bai, Z., Wang, K. (2020). Coronavirus pandemic reduced China's CO2 emissions in short-term, while stimulus packages may lead to emissions growth in medium-and long-term. Applied energy, 278, 115735.

Wang Q., Su, M. (2020). A preliminary assessment of the impact of COVID-19 on the environment–A case study of China. Science of the total environment, 728, 138915.

WHO (2020). Media briefing on COVID-19. Available from: https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020 (Accessed: 19/10/2021)

Climate reporting in EU: from NFRD to CSRD and beyond. Implications for Greece

Benjamin Karatzoglou, PhD
Researcher
venos@um.edu.gr

Abstract
The last decade EU has been enforcing laws requiring that certain large companies disclose information on environmental, social and governance (ESG) impact of their operations to help multiple stakeholders evaluate aspects of corporate non-financial performance and potentially promote corporate sustainability. Pertinent efforts culminated with the Non-Financial Reporting Directive (NFRD, 2014/95/EU), applicable to approximately 11,700 large-size, public-interest companies. As the adverse impact of climate change becomes aggressively apparent, multiple initiatives have emerged pressurizing companies to act and report on the impact of their activities and suggesting appropriate guidelines and frameworks. The voluntary nature of such requirements has limited their effective implementation since the provided information varies in terms of timing, transparency, quality, and assurance.
In 2019, the European Commission (EC) published guidelines focusing on reporting climate-related information as a supplement to NFRD. In April 2021, the EC adopted a proposal for a Corporate Sustainability Reporting Directive (CSRD) that extends the reporting scope to over 55,000 companies, making the process mandatory, audited, and digitally available to all. This paper presents the advancements in the field of climate reporting in the EU in anticipation of the CSRD issuance and critically analyses the suggested practices, probable shortcomings, consultation comments, and assumptions under which CSRD will contribute to transparency, clarity, and quality of the climatic reports produced.

Keywords: Non-financial reporting, Climate reporting, NFRD, CSRD proposal

JEL Codes: G11; G32; Q51; M4.

Sustainable banking practices and customer satisfaction: Empirical evidence from Generation Y

Athanasia Stauropoulou[1], Eleni Sardianou[1], Georgios Malindretos[1], Konstantinos Evangelinos[2], & Ioannis Nikolaou[3]

[1]*Department of Economics and Sustainable Development, Harokopio University, 17671, Athens, Greece*

[2]*Centre for Environmental Policy and Strategic Environmental Management, Department of Environment, University of the Aegean, Mytilene, Lesvos Island, Greece*

[3]*Business and Environmental Technology Economics Lab, Department of Environmental Engineering, Democritus University of Thrace, 67100, Xanthi, Greece*

astauropoulou@hua.gr, esardianou@hua.gr, gmal@hua.gr, kevag@aegean.gr, inikol@env.duth.gr

Abstract

The purpose of this research is to examine the determinants of the satisfaction that customers feel about the contribution of their bank to sustainability. Specifically, this paper focuses on Generation Y, since they have been more affected by the economic crisis during the development of its professional skills. This research contributes to developing knowledge regarding the impact of the integration of sustainability practices in the banking sector on customer satisfaction. The importance of customer awareness about the holistic involvement of banks in sustainability is recognized as a critical factor beyond their strict relationship to the financial dimension. The effective communication of sustainability practices of banks also has a direct impact on the level of satisfaction of Generation Y customers.

Keywords: Banking practices, sustainability, Generation Y, satisfaction, awareness.

JEL Codes: Q56; Q50; O44; M14.

1. Introduction

The integration of sustainable practices in strategic business planning is a common approach in many companies of different industries and activities. These practices address either social issues, environmental issues or a holistic approach to all aspects of sustainable development. A key part of business sustainability is the response and financial performance of its core business to the ultimate recipient who are consumers of products and customers of services. Ensuring financial sustainability a company is accustomed to making tactics that incorporate sustainable practices. The reasons why a company can step up the promotion of sustainable development vary. However, it is interesting if and to what extent this effort ends up being known by its customers and what dynamics are developed by the customer responses.

This study focuses on the determinant factors of customer satisfaction focusing on the sustainable practices of Greek banking sector. So, the effect of the awareness of the sustainable practices of the customers of the banking institutions on the classic concepts of consumer behaviours but oriented towards the sustainable dimension is examined. This study examines specifically sustainable satisfaction on Generation Y, also called Gen Y, Net Generation, Echo Boomers, Nexters etc. [1]. In particular, this research examines how the awareness of environmental and sustainable practices and the corporate image of banking institutions affect the sustainable satisfaction of customers belonging to the generation Y.

The purpose of this research is to examine the following research questions:

-What is the impact of awareness of the initiatives focusing in the environment and the contribution of sustainability regarding the satisfaction of generation Y customers of banking institutions?

-What is the effect of the overall image of banking institutions on the sustainable satisfaction of Generation Y customers?

-Are there differences in Generation Y demographics regarding the perceived level of satisfaction of sustainable practices?

This article has got the following structure: In the second part is presented the theoretical framework. In the third part, the methodological framework is presented and the data that were used in empirical analysis. In the fourth part, the empirical results are presented, while in the fifth part the conclusions of the analysis are summarized.

2. Theoretical framework

The banking sector, in particular, is an area with a specific form of customer relationship and often an area that is viewed with distrust and scepticism by customers due to the nature of its business, the impression that it may act inaccurately in the interest of their customers or show opportunistic behaviours [2]. Customer satisfaction is one of the central issues in the field of marketing and with significant interest in business strategy [3]. Satisfaction is the response to the fulfillment of the consumer, in the sense of judging the level of pleasure offered by a product or service. That is, the consumer feels that consuming a product or service satisfies a need and desire and that this fulfillment is enjoyable [4]. Outcomes from the satisfaction procedure are important tool for the field of marketing [5] especially in the context of interdependence and understanding of stages of consumer and purchasing behavior [6].

According to prevailing conditions, the involvement of companies goes beyond its main activity and incorporates practices which participate in achieving sustainable development. Respectively, the presence of the banking sector is becoming more noticeable in the form of initiatives that are oriented in the three dimensions of sustainability, economic, environmental and social. This is why sustainability must have a holistic approach and be assessed in a multidimensional context [7].

Businesses in order to benefit from the integration of sustainable practices, they need to take into account the different level of customer awareness. It is natural for every business to have different groups of customers in its clientele, which means a different level and ability to access information, but also to be able to process it. So in addition to mass information, targeted information can also bring effectiveness [8].

Market segmentation is an important tool for marketing managers [9]. The most common segmentation concerns the examination of demographic characteristics as a tool for targeted dissemination of information. Another used method of segmentation is generation segmentation, from which basic business data is derived. Its structure is already used and is based on the identification of the particular characteristics and attributes of each generation which can transform to a different consumer profile [10]. By knowing the social characteristics and the profile of its customers, the company can have better results, in terms of favoritism, intentions and behaviors. Knowing the dynamics of the market and if, for example, solving or contributing to solving a social problem is very important, and then targeted social practices may be more effective.

This research is focusing in generation Y, because marketers are particularly interested in this generation as on the one hand they are more consumption oriented, but on the other hand they also help to manage the obligations of households. Generation Y has also previous knowledge from marketing tactics in comparison with other generation [11].They have strong preferences and the goal of marketing is not only to gain their purchasing power, but also to increase their satisfaction with the ultimate goal of their loyalty, which previous research provide contradictory results [12].

In addition these individuals in this time period are active in the sense that they seek change for a better future and have social and environmental sensitivities such as global warming [11]. Another interested point is that although is very well educated [13], this generation has been more affected by the economic crisis during the development of its professional skills. It is the generation that was hit hardest by the financial crisis at the beginning of their professional activity, without it being easy to find a job that corresponds to either their educational background or making their entry into the workforce in general.

3. Methodology

To conduct the results on the determinants of sustainable satisfaction of generation Y by banking institutions, a statistical and econometric analysis was performed. A questionnaire was used as a research tool and sample consisted of 553 customers of Greek banking institutions belonging to generation Y. The research was conducted from April to June 2021.

In customer satisfaction research, satisfaction is an important part according to the international literature [14]. In this research is used the satisfaction variable adapted towards sustainable development in order to examine the research questions. Also the awareness and the perceived image can affect direct or indirect customer behaviors and intentions of the customers [15, 16 17]. As the aim of this research is to focus on sustainable development, the variables have been adapted accordingly to sustainability.

An ordered logistic regression model is estimated to predict the level of agreement regarding the statement ‘‘I am satisfied with my bank's involvement in sustainability practices’’ (answers: disagree: 0, neutral: 1, agree: 2).

The general specification of the proposed model question is the following:

$$satisfsust_i = b_1 gender_i + b_2 educate_i + b_3 income_i + b_4 awarenv_i + b_5 awarsust_i + b_5 image_i + \varepsilon_i$$

where satisfsust$_i$ is the latent variable measuring the agreement level of responder's satisfaction with his/hers bank's institution involvement in sustainability practices receiving the price 0 for disagree, 1 for neutral and 2 for agree; gender$_i$ is a dummy variable accounting for 1 if the respondent is female and zero if is male; educate is a dummy variable which states responder's educational level and is accounting for 1 if the responder is university graduate, master's degree holder or holder of doctoral degree and zero otherwise; income$_i$ is a dummy variable accounting for 1 if the responder's monthly private net income in euros is above 600€ and zero if it is below 600€; awarenv$_i$ is a latent variable measuring the level of responder's awareness concerning environmental practices of the responders' main banking institution, receiving the price 0 for not at all, 1 for a little bit, 2 for quite, 3 for very and 4 for absolutely important; awarsust$_i$ is a dummy variable accounting for 1 if the responder is aware of his/hers bank's institutions initiatives aimed at achieving sustainability (economic, environmental and social) which and zero otherwise; image$_i$ is a latent variable measuring the agreement level of the state that his/hers bank institution has a general positive corporate image receiving the price 0 for disagree, 1 for neutral and 2 for agree and ε_i is an error term. The empirical results from the estimation of ordered logistic are presented in the next section of this study.

4. Results

The results of the statistical and econometric analyses to estimate sustainable satisfaction with banks' institution involvement in sustainability practices are as follows:

4.1. Statistical analysis

The total sample used in the analysis was 553. The sample consisted of women 63% and men 37% (Figure 1). The average age of the sample was 32.77 years old. Specifically the average age of women is 32.63 years old and the average age of men is 33.01 years old. The 15.73% of the sample has completed the secondary education, while most of the responders (48.28%) were university graduate, 33.27% had a master degree and 2.71% had a PhD degree.

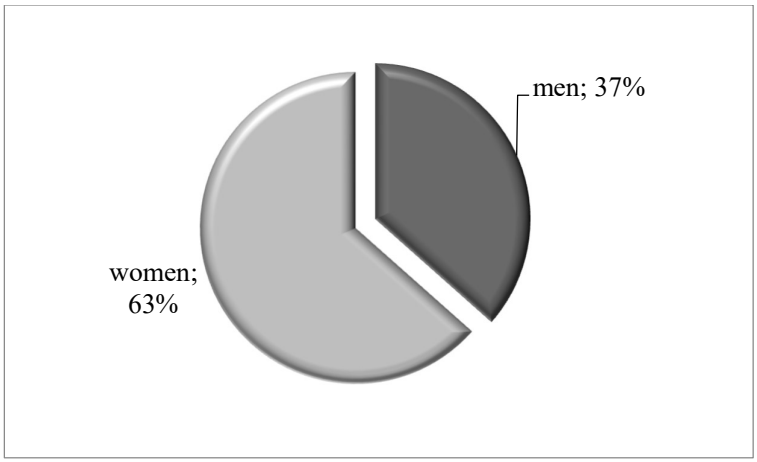


Figure 1. Percentage distribution of gender

Regarding the marital status, the 29.48% of the sample is married, half of the sample (52.62%) is not married, 16.09% is living with a partner and 1.81% of the sample is divorced or separated.

The 11.03% of sample has monthly net income from its main occupation under 300€, 27.49% is between 301€ and 600€, 26.04% is between 601€ and 900€.

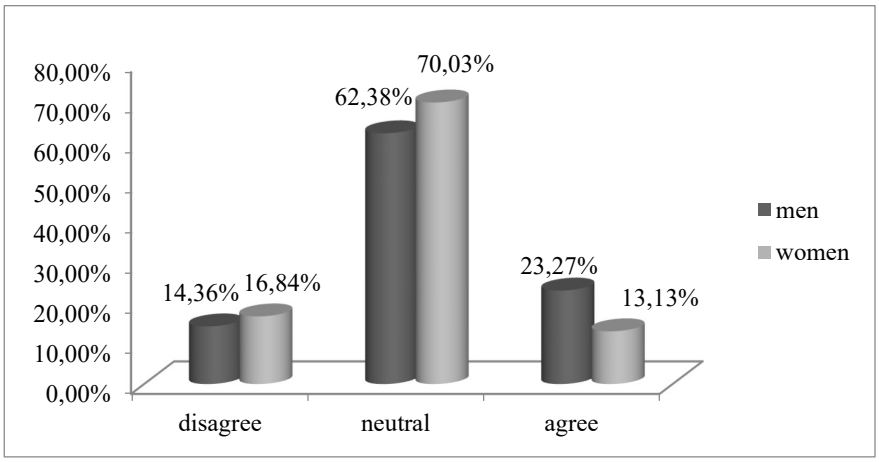


Figure 2. Percentage distribution of level of satisfaction of sustainable practices by gender

As far as the sustainable satisfaction of the responders, 14.29% of the sample declared that disagree with the statement that it is satisfied with its banks' institutions sustainable practices, 60.40% was neutral and 25.32% declared agree with the statement. There was not a significant difference between the level of satisfaction of sustainable practices between women and men (Figure 2). Furthermore, the 76.31% of the sample stated that it is not aware of banks' initiatives aimed at achieving economic, environmental and social sustainability and 65.10% declared that it is not aware of bank's institutions environmental practices. Finally, 61.48% of sample stated its banks' institution has a general positive corporate image.

4.1. Econometrical analysis

Table 1 presents estimation results of the ordered logistic equation's estimated coefficients with respect to responders' sustainable satisfaction with banks' institution involvement in sustainability practices. The parameters of the ordered logistic regression model were estimated by maximum-likelihood estimation. The focus of this analysis is the odds ratio, which present the effect of the independent variables. Marginal effects present the interpretation of the statistical significance of the independent variables in different agreement levels (disagree, neutral, agree).

Table 1. Estimated ordered logistic regression of sustainable satisfaction with banks' institution involvement in sustainability practices

Independent variables	Estimated coefficients	Odds ratio	Marginal effects		
			Disagree	Neutral	Agree
gender	-0.018	1.003	-0.002	-0.001	0.003
	(0.10)				
educate	-0.161	0.843	0.014	0.014	-0.028
	(-0.64)				
income	-0.108	0.928	0.009	0.009	-0.018
	(-0.53)				

awarenv	0.531***	1.668	-0.047	-0.041	0.088
	(4.86)				
awarsust	0.982***	2.651	-0.072	-0.114	0.186
	(3.75)				
imgen	1.107***	2.420	-0.098	-0.086	0.184
	(6.51)				
/cut1	0.083				
	SE: 0.371				
/cut2	3.621				
	SE: 0.416				
Log likelihood	-440.693				
Pseudo R^2	0.1434				
LR χ^2	147.52				

Disagree: 0, neutral: 1, agree: 2
n=553
*** represent level of significance at 1%
Z statistics are presented in parentheses

The main results are the following:
-An increasing positive correlation exists between the level of agreement regarding the satisfaction with banks' institution involvement in sustainability practices and the awareness of the environmental practices, at 1% level of significance. The odds of confirming satisfaction regarding sustainable practices are 1.668 greater for responders who are aware of environmental practices of banking institutions in comparison with others, ceteris paribus.
-An increasing positive correlation exists between the level of agreement regarding the satisfaction with banks' institution involvement in sustainability practices and the awareness of sustainable banking practices. The correlation is significant at 1% level. The odds of confirming satisfaction regarding sustainable practices are 2.651 greater for responders who are aware of bank's institutions initiatives aimed at achieving sustainability (economic, environmental and social) in comparison with others, ceteris paribus.
-Results indicate that there is positive statistical significant correlation between level of agreement regarding the satisfaction with banks' institution involvement in sustainability practices and level of agreement the that bank institution has a general positive corporate image. Responders, who have a higher level of agreement of the statement that their bank institution has a positive corporate image, are more likely to be satisfied from the sustainable practices. Specifically the odds of reporting agreement are 2.420 greater for the responders who agree with the positive corporate image, ceteris paribus.
-Finally, there is no statistical significant correlation between level of agreement regarding the satisfaction with banks' institution involvement in sustainability practices and gender, educational level and income.

5. Conclusions

This research aimed to investigate the determinants of satisfaction with the sustainable practices of the banking institutions of the customers belonging to the generation Y. The results showed that awareness has a significant effect on the satisfaction of these customers. In particular,

customer awareness of the environmental practices of banking institutions leads to higher levels of satisfaction regarding involvement of banking institutions in sustainable development. Also, customer awareness of the sustainable practices of banking institutions is even more likely to lead to a higher level of satisfaction of Generation Y regarding the sustainable practices. This is a basic conclusion from which the importance of communicating the initiatives of banking institutions to their customers is drawn. Especially the generation Y which is the first generation with such an obvious and direct relationship with all the ways of communication is a typical example of how important the role of communication is. The overall corporate image of the banking institution has a correspondingly significant effect on the sustainable satisfaction of generation Y also.

It is pointed out, from the results of the research, that the banking institutions by strengthening and promoting the practices that are not related to the main activity of the industry and creating a positive framework that concerns their corporate image will enhance the level of sustainable satisfaction. Generation Y, as it is a generation that has growed up and learned to have a daily access to social networks, internet [18] and using more all the non-traditional ways of information (newspaper, TV, radio), needs the corresponding communication transmission from the companies with it is involved. The results showed that the efforts of sustainability driven practices are taken into account and as long as the customer of generation Y is aware of these efforts, they will also feel the corresponding satisfaction.

References

Eisner S P 2005 Managing generation Y *SAM Adv Manage J*, **70** 4–15

Saiedi E, Mohammadi A, Broström A and Shafi K. 2020 Distrust in banks and fintech participation: The case of peer-to-peer lending *Entrep Theory Pract* **63** 1–28

Churchill Jr G A and Surprenant C 1982 An investigation into the determinants of customer satisfaction *J Mark Res* **19** 491–504

Oliver R L 1997 *Satisfaction: A behavioral perspective on the consumer* (New York: Irwin/McGraw-Hill)

Jamal A and Naser K 2002 Customer satisfaction and retail banking: an assessment of some of the key antecedents of customer satisfaction in retail banking *Int. J. Bank Mark.* **20** 146–160

Jamal A 2004 Retail banking and customer behaviour: a study of self concept, satisfaction and technology usage *Int. Rev. Retail Distrib. Consum. Res.* 14 357–379

Aras G, Tezcan N and Furtuna O K 2018 Multidimensional comprehensive corporate sustainability performance evaluation model: Evidence from an emerging market banking sector *J. Clean. Prod.* **185** 600–09

Pomering A and Dolnicar S 2009 Assessing the prerequisite of successful CSR implementation: are consumers aware of CSR initiatives? *J. Bus. Ethics* **85** 285–301

Johnson R M 1971 Market segmentation: A strategic management tool *J Mark Res* 8 13–18

Williams K.C and Page R A 2011 Marketing to the generations *JBSB* **3** 37–53

Tsui B and Hughes L Q 2001 Generation next *Advertising Age* **72** 14–16

Priporas C V Kamenidou I Kapoulas A and Papadopoulou F M 2015 Counterfeit purchase typologies during an economic crisis *Eur. Bus. Rev.* **27** 2–16

Wolburg J M and Pokrywczynski J 2001 A psychographic analysis of Generation Y college students *J Advert Res* **41** 33–52

Jamal A and Naser K 2003 Factors influencing customer satisfaction in the retail banking sector in Pakistan *Int. J. Bus. Manag. Sci.* **13** 29 J. Brand. Manag. 53

Kandampully J and Suhartanto D 2000 Customer loyalty in the hotel industry: the role of customer satisfaction and image International journal of contemporary hospitality management

Huang P L Lee B C and Chen C C 2019 The influence of service quality on customer satisfaction and loyalty in B2B technology service industry *Total. Qual. Manag. Bus. Excell*. **30** 1449–65

Pappu R Quester P 2006 Does customer satisfaction lead to improved brand equity? An empirical examination of two categories of retail brands *J. Brand. Manag.* **15** 4–14

Bolton R N Parasuraman A Hoefnagels A Migchels N Kabadayi S Gruber T Komarova Loureiro Y and Solnet D 2013 Understanding Generation Y and their use of social media: a review and research agenda *J. Serv. Manag.* **24** 245–67

The socioeconomic and environmental impact of exploration and exploitation of hydrocarbons in maritime areas and the case of Greece

Andreas Stergiou
Department of Economics, University of Thessaly, 28hs Octovriou 78 Volos (Greece)
Snandreas@econ.uth.gr

Abstract
Notably, the exploration and exploitation of hydrocarbons in a maritime area have considerable social, economic and environmental impact. Both activities are of extremely complex nature and hence their success is subject to many and diverse factors. Although there are some common socioeconomic and environmental denominators, the impact of these projects strongly vary. International experience has showed that in some countries the monetisation of hydrocarbons, extracted in maritime areas, generated advantages to both diversification of the economy, the development of the processing industry, they smoothed out volatility, stimulated employment and guaranteed long-term energy security, thereby maximizing the economic benefit to the economy without harming the environment. However, much more are the oil and gas producing countries, in which economic exploitation of hydrocarbons has not been a bonanza or a windfall and where serious political difficulties have arisen over the distribution of oil and gas revenues but rather turned out to be a curse, causing unrepairable harm to the environment, impeding growth, igniting internal or cross-boundaries clashes, attracting foreign interventions, deepening existing conflicts and undermining the creation of a stable representative, pluralistic, democratic system.
However, unlike in other policy areas, it is not possible to identify a generally accepted international government policy concerning the development and management of the natural gas industry. The paper takes stock of some characteristic examples of extraction and monetisation of hydrocarbons discovered in the sea, identifies major trends and tries to project them to the specific circumstances that prevail in Greece.

Keywords: Hydrocarbons, environment, offshore drilling, socioeconomic impact of the exploitation of fossil fuels, Greece and hydrocarbons reserves

JEL Classification: Q35, Q38, Q47, Q48, Q53

Development of energy resources: the international experience

Exploration and exploitation of hydrocarbons are subject of a constant evolution both in technological and institutional terms. Despite the relevance of the topic, accurate analyses on the exact social and environmental impact of the extraction of hydrocarbons are sparse. Companies-shareholders are mainly concerned about the profit deriving from such kind of activities, while national leaders are mainly concerned about their national constituencies, since they preside over national economies and pursue national interests. On the other side, NGO's are mainly focused rather on the repercussions than the positive consequences of natural resources development.

Monetisation of energy resources has been a field of contention between scholars from various disciplines. The majority of the scientists dealing with these issues are in agreement that hydrocarbon resources are not destiny. There are choices to be made which determine whether resources are a boon or a curse. Failing to take advantage of resource abundance may be a missed opportunity, but failure to pursue good policies can also very quickly entail a resource curse.

In the energy economics, there are two main schools of thinking pertaining the development of fossil natural resources, the proponents and the rejectionists. The proponents of the exploration and exploitation of hydrocarbons argue that an efficient management the development of hydrocarbons can boost long-lasting prosperity for a society. Revenues emanating for the monetisation of hydrocarbons can, if utilised efficiently, generate advantages to both diversification and the development of the processing industry, smooth out volatility and stimulate employment. Of all the resource-rich nations, Australia, Botswana, Canada, Chile, Malaysia, Denmark (Greenland), and Norway are considered to be the most successful ones in terms of their economic growth and diversification of their economies.

The economists who argue in favour of the extraction and development of hydrocarbons, with the exemption of some isolationist US economists who completely disregard the environmental impact controversial methods of extraction of gas, such as franking, might have on the planet, do not underrate the ecological factor. However, they assert, that it is impossible to substitute the majority of hydrocarbon resources with alternative power resources in the near term and the criticism of energy companies with regard to their responsibility for climate change should lead not to destruction of the industry but to the search of sustainable means for its development. Some other proponents acknowledge the value of the renewable energy but they argue that nothing less than a surplus in the energy balance derived by an ecological friendly extraction of existing hydrocarbons can boost efforts to shift away from fossil fuels and replace oil and coal with renewable energy sources (The World Bank 2011; Hellenic Hydrocarbons Resources Management SA, 2020; The Greenland home rule government Bureau of Minerals and Petroleum, 2004; Yergin, 2011: 438-647; Litvinenko 2020).

The ''rejectionist approach'' is based on economic and environmental arguments as well. Their economic arguments, based on historical experience, are related to the side-effects of the monetisation of hydrocarbons such as the overheavy reliance on commodity exports that, in the long-term, tend to affect economic growth and competitiveness of other businesses and economic sectors prompting inflationary pressure on salaries and prices caused from the increased public income (Dutch disease)[1]. In their well-known study about the so-called ''resource curse'', Sachs and Warner, showcased that in the long term, nations drawing a large share of GDP per capita from raw material exports have slower growth rates than countries whose raw materials constitute a smaller share of exports. Especially in developing countries the rapid economic growth from the monetisation of hydrocarbons and the followed creation of boomtowns has been

[1] The phenomenon was first observed in connection with large Dutch finds of natural gas in the late 1950s and their long-term repercussions on the Dutch economy.

interlinked with various social problems such as the increase in immigration, social disorganization, economic inequality and increase in crime rates.

Another usual side-effect of hydrocarbons windfalls is the emergence of so-called 'rentier states'. Notably, the concept of the 'rentier state' has been introduced by Hossein Mahdavy (Mahdavy 1970: 428-467) to define a state that receives on a regular basis substantial amounts of external economic rents that ''paradoxically'', in the end turn out to have negative economic and political consequences for the well-being of the state. The main reasons for that lies on the fact that the state budget becomes more and more dependent on the revenues from natural resources sold on foreign markets with prices determined by external conditions and not on taxes. As the state is largely freed from the need to levy domestic taxes, institutional capacity remains weak despite over-blowed administration. In such resource-rich countries success in the natural resource industry determines success in society, and control over the resource industry determines political power. The lack of democratic traditions makes the distribution of income intransparent, fuelling corruption and huge social disparities (Huliaras and Sotiropoulos 2018, 5-8).

Above all, the rejectionists warn about the environmental hazards on- and off-shore exploration and drilling of hydrocarbons are associated with. In this regard they commonly pinpoint the damages on the ecosystems: harm to animal populations, particularly migratory birds and marine mammals, harm to vegetation and the ground; pollution from oil spills due to accidents or reloading and transporting oil; repercussions on human health: safety risks for neighbouring communities and oil industry workers (Homer-Dixon 1999; Colgan 2014: 198-205). (Engel, 2013; VanDeveer, 2013; Frankel, 2010; Sachs and Warner 1995).

There are numerous cases where oil and gas booms created economic growth and raised living standards, an excellent welfare state, low inequality and good progress in gender balance. Distinctive examples are Norway, Canada, the oil-rich countries of the Middle East, Russia, and the United States (North Dakota today and Ohio and Pennsylvania in the early 1900s), where exports of oil and gas have become very important elements of its economy precipitating prosperity and enforcing a stable democratic and transparent system. It was also the case with Germany, Italy, France and the Benelux Countries, which co-founded the European Coal and Steel Community in the 1950s laying the foundations for a long-term cooperation that ended up in the European Union (Stergiou, 2017: 258-259 Hemmings 2018; Aslani, Hamlehdar and Saeedi 2017).

However, much more are the oil and gas producing countries, in which economic exploitation of hydrocarbons has not been a bonanza or a windfall and where serious political difficulties have arisen over the distribution of oil and gas revenues but rather turned out to be a curse, impeding growth, igniting internal or cross-boundaries clashes, attracting foreign interventions, deepening existing conflicts and undermining the creation of a stable representative, pluralistic, democratic system. This equally applies on advanced capitalist and undeveloped countries. A very recent example comes from Scotland, where oil played a major role in Scottish break away aspirations from the United Kingdom (King, 2012). More classical examples constitute Nigeria and Kongo, where energy resources became a source of serious internal ethnic and political conflicts and serious violations of human rights, inspired by distributional conflicts among the different tribes in the country (Human Rights Watch, 2016; Khakee, 2010, pp. 175-195).

In the past, fossil fuels were the primary link between energy and conflict, as control and transport of oil and gas drove political unrest, wars over territory, and interventions by powerful countries in order to secure their supply chains. Ever since the World War II, the industrialised countries have relied on crude oil as fuel for their economic development and growth. Among them, the United States have been for most of the time the largest producer and exporter, while other developed countries, such as Japan or European countries, had few domestic sources, what, turn, rendered them dependent on cheap Middle Eastern petroleum. Unlike many other

commodities, oil is located only in certain geologic regions of the world, making it more susceptible to political manipulation by those who have control over it (Mingst, 2008, p. 277).
So far efforts to reduce the amount of fossil fuels humans use, a process widely known as decarbonization, have focused on managing demand and urging countries move toward an energy mix less dependent on oil, gas and coal. In geopolitical terms, this development is expected to be unfolding at the expenses of states that depend on fossil-fuel exports or remain heavily relied in the use of hydrocarbons. Decarbonization could destabilize many oil- and gas-producing countries, especially the so-called rentier states with undiversified economies, if they are not offered realistic alternatives for economic development able to generate analogous state income. This large-scale socioeconomic and political instability, in turn, may have region-wide ripple and tremendous spill-over effects.
That's way, given its highly differentiated geographic and technical nature in comparison to coal, oil, and natural gas, renewable energy makes up a game changer in interstate relations. While fossil fuel resources are fixed and finite, renewable energy sources are abundant and intermittent; While fossil fuels rely on large centralised production and processing installations, many transport modalities (pipelines, tankers, rail, road) and efficient storage options (refineries, storage hubs, harbor facilities, depots, cylinders) well-suited for long-distance (global) trade, renewable energy production lends itself more to decentral generation, involves rare earth materials in clean tech equipment and their distribution is highly regionalised. Thus, the transition towards renewables will reshape strategic realities, conflict among countries and certainly entail a shift from oligopolistic to more competitive markets. On the other hand, as it has already been mentioned, increasing competition for rare earth materials and clean tech know-how between countries is also highly likely (Scholten, 2018: 1-4).
Beyond that, a decarbonized global energy sector is expected to need cumulative investments in the tens to hundreds of trillions of dollars between now and 2050. Due to its size, the current climate-business environment is therefore prone to corruption risks. Yet such corruption risks are rarely explored within the research community. Much of the extant literature on energy and corruption focuses on fossil fuels, especially oil, coal, and natural gas. However, evidence is emerging that corruption risks also feature in renewable energy markets (Sovacool, 2021).

The socioeconomic impact of offshore resources development: the international experience

The exploitation of offshore hydrocarbons essentially differs from the onshore activities. The challenges for oil and gas offshore exploration are more significant than onshore. The operational costs required for offshore exploration are more expensive than onshore. The environmental impact of offshore explorations might be bigger, while the social impact is, as a rule, less than in onshore schemes. The provisions needed to drill onshore wells are somewhat more accessible than offshore. Examples of onshore works are onshore refineries and boreholes. However, the advantage of an offshore rig is that the structure can be moved because of the use of floating platforms such as Floating Production Storage and Offloading (FPSO) and Tension Leg Platform (TLP). Moreover, in offshore activities, exploration and exploitation are carried out using fixed offshore platforms (jacket, jack-up) or floating (PWYP INDONESIA 2021).
Offshore oil and natural gas activities engulf several stages. The exploration process normally begins with a review of existing geological and geophysical data about potential reservoirs, it continues with a marine seismic survey and ends with drilling. Should a company decide that it wants to proceed to oil and natural gas production, the next step is development that can last from five to 10 years, depending on the size of the project. Once all of the accessible oil and natural gas reserves in a field have been produced, the project should be decommissioned, meaning that wells are plugged and abandoned, infrastructure is removed and the site is cleared.

These multifaceted activities have a considerable socioeconomic impact that needs to be assessed at many levels and over a long period of time. Their basic aspects are:

1) Increase of public expenditure that, in turn, can boost social welfare benefits, infrastructure projects and so on. There are multiple layers of profits-based rent extraction mechanisms such as special profits taxes, windfall profits taxes, oil and gas production sharing, and/or corporate income taxes. Profits-based mechanisms which include mostly taxes and production sharing costs are the most common features found in license agreements or PSCs (Production Sharing Contracts) (Agalliu, Montero, Adams, Gallagher, 2018).
The most common concept is the ‘‘state take’’ as it is defined below:

$$\text{Government Take (\%)} = \frac{Total\ Government\ Revenues\ Gross}{Gross\ Revenues - Total\ Costs}$$

Where: Total Government Revenues = All revenues from royalties, taxes, production sharing, and government equity participation (full-cycle). Gross Revenues = All revenues from the sale of hydrocarbons (full-cycle) and Total Costs = All capital costs and operating costs (full-cycle). In practice, sharing the rents equitably is difficult. Foreign participation is necessary when there is not the required technical expertise, skilled labor and financial resources to explore and exploit the resources. The formula foreign firms work is simple: recouping their costs, make a normal profit and self-insuring for projects which might prove barren. With asymmetric information and transfer pricing, however, the foreign firm may present the accounts so that cost recovery appears to take longer than in reality. If the state fails to specify social, politically sensitive matters, environmental or work safety obligations or to hold the partner responsible for other negative externalities, then the partner is not obligated to spend money on these matters (Pomfret, 2012: 152).

2) increase in the demand of labour[2] due to the direct production activities, exploration and drilling, the construction of facilities and infrastructure, extraction and distribution (supply chain). In addition to permanent drilling personnel working on the rig, in connection with the actual operation of the rig a large number of maintenance and service functions are normally put out to tender, for example: painting the rig, security, maintenance of electrical installations, catering services, medical services, offshore nursing services, laundry and supply of work clothes, sea and air transport to and from the rig, maintenance of main generator, maintenance of turbine, single anchor loading, chemical supplies, gas supply, maintenance of lifeboats/rafts, servicing cranes, repair and maintenance of valves, compressors and pumps, rig inspection, preparation of local storage facilities. Furthermore, the capital investment by the oil and natural gas industry might have an indirect impact on jobs and the labour income. In the case of Greenland, for example, hydrocarbons development generated a need for sailors, divers, metal workers, electricians, harbour and logistics personnel, IT specialists, hotel and catering staff, engineers, geologists, office staff, builders, pilots, steward(esse)s, airport personnel etc. (The Greenland home rule government Bureau of Minerals and Petroleum, 2004: 48).

3) Finally, household spending of labour and proprietor’s income earned either directly or indirectly from the oil and natural gas industry’s spending generate the so-called induced impact on jobs. To meet the demand for goods and services from an industry, purchases are made in other industries. These purchases in turn spark still more purchases by the industry’s suppliers, and so on. Additionally, employees and business owners make personal purchases out of the

[2] While natural gas and oil industry’s effect on total employment has been registered in the most cases, the level of jobs supported by an energy sub-sector is a fundamentally different kind of statistic than estimates of changes in jobs resulting from changes in investments or policies in the energy sector. Data are scarce and there are large uncertainties with published numbers, so that point estimates should be treated with caution.

additional income that is generated by this process, sending more new demands rippling through the economy. Additional economic impact was generated by shareholder spending out of dividends received from oil and natural gas companies. The jobs, labour income (including wages and salaries and benefits as well as proprietors' income), and value added supported by this cycle of spending. For example, it is estimated that in 2015 in the USA the oil and natural gas industry directly provided 2.8 million jobs for American workers, paid 289.6 billion dollars in wages, salaries and fringe benefits and proprietors' income, and generated 602.6 billion dollars in GDP. It also has supported 10.3 million full- and part-time jobs through direct employment and indirect support to other sectors, because for every direct natural gas and oil job, an additional 2.7 jobs are supported elsewhere in the economy. These jobs made up 5.6 percent of the nation's total employment, while the overall economic impact as a result of wages, taxes, capital investments and support to other industries reached 6 percent of the US GDP (American Petroleum Institute, 2017).

Revenues emanating from monetisation of hydrocarbon are not income in the traditional sense but arise from "tapping" the national wealth. Therefore, some countries have created revenue funds (Sovereign Wealth Funds) as a mechanism to balance the impact of volatility on the economy in the event that the economy is exposed to significant cyclical fluctuations and in order to distribute the wealth between generations. The most famous is perhaps the Saudi Arabian Public Investment Fund. Established in 1971 has evolved and grown from a financial support fund for strategic projects to one of the world's largest sovereign wealth funds. Those funds' real effect on inflation, broad money volatility and price volatility is depended on whether the appropriate fiscal policies and institutional capacities are in place. The rapid and widespread emergence of the sovereign wealth fund industry (meanwhile estimated to some trillion Dollars) has been one of the most important developments in international finance and resource economics in the past decades (Van den Bremer, Van der Ploeg, Wills, 2016: 113-131; Tsani, 2013:181-195).

In the early 1990s Norway set up a Petroleum Fund with the objective of ensuring that revenues from hydrocarbon activities are managed so that, as far as possible, society avoids impacts similar to the Dutch disease, i.e. implement economic policies which prevent inflation and rising costs. Many countries followed Norway's example. The Republic of Cyprus passed in March 2019 a bill establishing a national investment fund to manage future revenues from hydro-carbons, disconnecting gas revenues from public debt. The bill provides that public debt that will be serviced by fund resources only if it exceeds 80% of the GDP. Azerbaijan also set up a sovereign wealth fund (SOFAZ) in late 1999 in order to avoid income volatility, to achieve intergenerational equity, to transform resource wealth into more productive assets as well as to be able to finance social projects. While SOFAZ has gradually become the leading part of the country's public finance system, its contribution to long-run economic development is still questionable: transparency applies only to the income side of Azerbaijan's oil fund while the expenditure side remains opaque (Aslanli, 2015: 114-121).

Illustrative Examples of Sovereign Funds Used to Manage Commodity Wealth. Source: Engel, 2013: 9

	Basic Facts	Mandate	Investments/Projects
Botswana *Pula Fund* Diamonds and Minerals	• Worth over $6 billion • Founded in 1994	• Pula Fund is used "to transfer mineral wealth to future generations"	• "long-term instruments overseas in a range of major currencies and in a mix of long-term fixed income securities and equities"
Chile *Economic and Social Stabiliza-tion Fund2* Copper	• Worth $14.86 billion • Surpluses over 1 percent of GDP are deposited into the fund • Founded in 2007 (derived from Copper Stabilization Fund, established 1985)	• Focuses on smoothing the short-run business cycle and variance in copper prices, and on minimizing the need for government-issued debt	• Over 80 percent of the fund's value is held in international sovereign bonds • Maintains a high level of liquidity based in dollars, euros, and yen
Pension Reserve Fund3 Copper	• Worth $5.83 billion • At least 0.2 percent of GDP deposited annually into the fund • Founded in 2006	• Given the forecasted increase of aged population, the fund is aimed at guaranteeing the so-called solidarity pensions	• Over 60 percent of the fund's value is held in foreign sovereign and government-based bonds (including inflation-indexed bonds)
North Dakota *Legacy Fund* Oil and Natural Gas	• Worth $1 billion • Founded in 2011	• With finite revenues from oil and gas, the fund seeks to "defer the recognition of 30 percent of this revenue for the benefit of future generations" and "to preserve the real, inflation-adjusted purchasing power of the monies deposited into the fund"	• Short-term bonds, however, there is a recent push to move some investing into stocks
Norway *Government Pension Fund Global* (called Petroleum Fund until 2006)4 Oil	• Worth $686 billion • 3.66 percent net real return over last 10 years • Founded in 1990	• "to give the government room for manoeuvring in fiscal policy should oil prices drop or the mainland economy contract" • This fund will deal with expected increases in public expenditures due to Norway's aging population	• Property in U.K., France, and Switzerland • Wide variety of bonds • Holds a vast number of global stocks, owning small percentages of many companies (including Air China, Target, Barclays, and General Electric)

The fate of the Caspian countries is a striking example of the emergence of so-called rentier state phenomenon. Until 2008 Kazakhstan's oil industry experienced a boom favoured by the high world market prices, which had as a result that fuel accounted for 70% of all merchandise exports and the country's gross domestic product rose on average by 8% per year. However, from this

oil boom only a small portion of the Kazakh population benefited. Apart from the fact that the oil industry did not create many jobs and suppressed the development of other economy sectors, the big income from the export of the natural resources brought about the so-called rentier state phenomenon. The oil revenue fund set up in Kazakhstan to curb this tendency failed to diversify the structure of the economy and to mitigate dependence on natural resources, paving the way for the so-called ‘‘resource curse’’ (Azhgaliyeva, 2014: 157-183; Satpayev and Umbetaliyeva, 2015: 122-129).

Since 2001, as Azerbaijan started receiving revenues from its oil and gas sector, according to the terms of the so-called “Contract of the Century”, signed in 1994 between the Azeri government and a BP-led consortium of western companies, GDP growth averaged 16% a year due to strong direct and public investment and the high international energy commodities prices. Despite development of the oil and gas sector, the other sectors of the economy remained undeveloped and fragile. Given that the oil and gas industry were only responsible for less than 2 % of employment in Azerbaijan, while agriculture employs nearly 50% of the country, the contribution of the natural resources’ monetisation on the labour market has been very unsatisfactory. The large oil and gas revenues, however, enabled the government to use some revenues to reduce the poverty (increase minimum salaries and pensions) or to finance impressive projects such as the establishment of new Universities (ADA University) and the transformation of the coastline along the Caspian Sea. Nevertheless, although social transfer measures have reduced the number of people below the poverty line, they did not automatically lead to sustainable poverty reduction, while the corruption upsurged (Ciarreta and Nasirov, 2012: 283-284; Farid Zulfigarova and Matthias Neuenkircha, 2020).

High revenues from gas did not spare Turkmenistan from the repercussions caused by the over-reliance on external rents than taxes, preparing the soil also in this case for the emergence of a ‘rentier state’’. This, in turn, obliterated the need for the government to seek public support and legitimation for spending. The lack of checks on executive power further undermined the weak democratic system. The country’s large gas rents were largely spent on prestige projects in support of a personality cult or disappeared into foreign bank accounts. Populist measures to provide free or low-cost basic needs were provided at the government’s pleasure without granting to the residents property rights or security of supply of power, heating or plumbed water. In the absence of the possibility to raise money from the financial markets, the attempts at increasing productive capacity or diversification of the economy also turned out to be inefficient (Pomfret, 2012: 153).

The environmental impact of offshore drilling: The international experience

In comparative perspective, offshore drilling is mostly linked to pollution caused by accidents and oil spills that, in turn, entail not only environmental degradation but also socio-economic impacts on recreational and tourist activities such as fisheries, mariculture, but also on power plants, shipping, salt production or seawater desalination, and seafood industry.

Norway constitutes one the few exemptions. Successive Norwegian governments accomplished indeed a responsible management of natural endowment that has essentially helped the country to move fast towards its goal of transition to green energy and to create a more environmental friendly energy mix. While Norway is one of the richest countries in fossil fuel reserves and production, approximately 96% of electricity is generated by hydropower (Hemmings 2018; Aslani, Hamlehdar and Saeedi 2017).

In the most cases however**,** oil and hazardous and noxious substances products released at sea impact an environment in many ways: with chemical toxicity giving rise to lethal or sub-lethal effects or causing impairment of cellular functions; ecological changes, primarily the loss of key

organisms from a community and the takeover of habitats by opportunistic species; indirect effects, such as the loss of habitat or shelter and the consequent elimination of ecologically important species. The nature and duration of the effects of an oil spill depend on a wide range of factors such as the quantity and the type of spill, its chemical characteristic and its behaviour in the marine environment, the location of spill in terms of ambient conditions, physical and ecological characteristics, the season and the prevalent weather conditions (REMPEC 2021).

As widely known, in 2010 one of the worst environmental catastrophes in human history took place in the United States, the oil spill in the Gulf of Mexico. Additionally, the explosion and sinking of the Deepwater Horizon oil rig in the Gulf of Mexico killed 11 people. Over the course of 87 days, the damaged Macondo wellhead, located around 5,000 feet beneath the ocean's surface, leaked an estimated 3.19 million barrels (over 130 million gallons) of oil into the Gulf of Mexico—making the spill the largest accidental ocean spill in history. As much as 20 percent of the spilled oil may have ended up on top of and in the seafloor, damaging deep sea corals and potentially damaging other ecosystems that are unseen at the surface due to the chemicals in oil, which are called polycyclic aromatic hydrocarbons. Some of these are known to cause cancer. In all of the waters that were affected by the spill, commercial and recreational fishing could resume a year later (The Ocean Portal Team, 2018).

The case of Caspian Sea is more representative for the environmental hazards the offshore drilling might entail and of inordinate importance for this study, because the Caspian Sea has much in common with the Mediterranean Sea that is a semi-closed sea. The Caspian Sea, bordered by Azerbaijan, Iran, Kazakhstan, Russia and Turkmenistan, is a unique ecological system with rich natural resources, which include mineral, biological, agroclimatical, balneological, and recreational components. It is also the world's largest inland body of water, about the size of Japan. Intensive oil and gas development in the Caspian region resulted in extensive air, water and land pollution, wildlife and plant degradation, exhaustion of natural resources, ecosystem disturbance, desertification and considerable losses in biological and landscape diversity. Moreover, the pollution, along with declining water levels due to climate change, has posed a severe threat to many species and the future of the sea itself at risk. The UN Environment Programme has drawn attention to the fact that the Caspian ''suffers from an enormous burden of pollution from oil extraction and refining, offshore oil fields, radioactive wastes from nuclear power plants and huge volumes of untreated sewage and industrial waste introduced mainly by the Volga River''. Environmental damage has exceeded revenues from exploitation of natural resources. Negative environmental changes seem to have caused growth of human morbidity and mortality. Life-rate in the Caspian littoral states is lower for 15-20 years than in developed countries. Some areas have become dead zones, and the Caspian shelf mainly loses its validity as a place for spawning of the Caspian Sea fishes. The fishing activities are also undermined, as the entire caviar industry is in danger. For example, the sturgeon fishery is a traditional and well-known activity because of the value of the caviar and fish. However, in recent times, there has been a drastic decline in the sturgeon catch and a mass loss of seals Caspian sprat. (Palasciano, 2019; CASPINFO).

In Nigeria development of hydrocarbons has also brought about a complete and senseless desecration of the environment especially in the oil sector (the case of the Niger Delta is still a case at hand), loss of indigenous occupation among local communities, corrupt practices and rural to urban migration in search of perceived oil related white-collar jobs among others. Given that fact that the overwhelming part of the oil earnings (over 80 per cent of Nigeria's wealth) go to only one per cent of the population, it would not be erroneous to conclude that exploitation of hydrocarbon resources in Nigeria has not made any positive and significant impact on the lives of Nigerian citizens and the economy in general (Agbaeze and Ukoha, 2018).

Regarding the Mediterranean Sea, international environmental organisations have repeatedly called attention to the significant accidents caused by offshore activities that could have long term adverse consequences for the fragile ecosystems and biodiversity of the Mediterranean Sea due to its enclosed nature and special hydrodynamics as well as negative consequences on the economies of the Mediterranean countries especially for tourism and fisheries (United Nations 2013).

In the context of the ‘‘green theoretical school’’ of international relations environmental degradation is perceived as violence, because the latter is defined as an act or process preventing people from realising their potential. In line with this assumption, environmental degradation prevents the achievement of ‘‘positive peace’’, which is a situation where there is not just the absence of war, but the presence of justice. From a green perspective peace also involves establishing a harmonious relationship between human beings and other living entities, whereas achieving security requires nothing less that a change in world view. The scarcity of resources can generate conflicts between states, particularly where are existing disputes about territory and ownership and control of resources. The increasing scarcity of renewable resources is also linked to the rise in violent conflict within countries with significant implications for relations between states (Steans and Pettiford, 2005, 216-222).

THE GREEK CASE

Notably, Greece is heavily dependent on natural gas, which continues to support the country’s power production at a growing rate, while the fuel’s share in the area of industrial and domestic consumption is also expanding. It is estimated that in 2020 electricity production absorbed 65% of total domestic demand for natural gas. Since almost 99.5 per cent of the petroleum used in the Greek energy market is imported, the discoveries of gas reserves in the Southeast Mediterranean excited Greece’s interest in exploration of gas. Geological formations and geometric structures in the southern Ionian Sea and especially of in offshore regions of Southwest and Western Crete seem to resemble the Zohr field in Egypt, the fields of Aphrodite, Calypso, Glafkos and the geological structures of Onesiphoros in Cyprus or the Leviathan in Israel. Against this background, Greece granted licences for exploration and exploitation of hydrocarbons to Greek and foreign companies (French, American, Spanish) in various continental and maritime parts of its territory. During the period 2014-2019 Parliament ratified 11 lease agreements for concession of exploration and operation rights. The concessions in the northern Ionian Sea and mainland Western Greece are expected to yield crude oil deposits, with natural gas appearing further south, as indicated by the results of drilling in the past decades. The concessions in the southern Ionian Sea, especially to the west and south of Crete, feature great sea depths and no previous drilling.

In the wake of the devastating economic crisis that inflicted Greece from 2010 onwards, the possibility of discovery of oil and gas has unleashed an unprecedented hydrocarbon frenzy within the Greek society, featuring future oil and gas revenues as the spearhead of the long-desired economic recovery. Indeed, many experts have argued that drilling for oil and natural gas reserves in Greece may not only increase the country’s revenues, create new job opportunities and technological innovations but also end its dependence on oil and gas imports, on which it spends billions of euros each year (Mezartasoglou, Stambolis, Perellis, Koutroumbousis, 2020: 9-10).

After a cooling down of the energy giants in natural gas quantities in the Southeastern Mediterranean in 2019-2022, the 2021 energy crisis has revived interest in the unexplored reserves south of Crete and in the Ionian Sea, whereas simultaneously exploration in other parts of the Greek territory such as in the maritime area of Patraikos Gulf has been suspended.

Some experts believe that the Eastern Mediterranean region subsumes into the category of regions in which the transition process to the green economy and climate cooperation is linked to the natural gas as transitional fuel in the objective to attain long-term decarbonisation energy and climate goals. Since the East Med countries lack significant nuclear capacity, are heavily reliant on gas consumption and have significant quantities of natural gas (though some of them are still assumed), gas should remain an important energy source to back up intermittent renewables and replace more polluting oil and coal in the medium term (Franza, 2021: 28).

On the same trajectory, it has been argued that hydrocarbon exploration will become imperative in the next years, since Greece is set to eliminate lignite completely by 2028, as a major indigenous fuel. Reduction in carbon dependency is strongly associated with the controlled conservation of traditional energy sources due to their high energy efficiency compared to the alternatives. For this reason, as lignite is being withdrawn, the argument goes, Greece should within the next few years, make every effort to produce natural gas from its own reserves so that it can gradually cover most, or even all, of its consumption (5-8 BCM / year) (Oikonomopoulos 2020).

In the current EU energy policy framework the exploration and exploitation of natural gas is still consistent with the ambitious EU-energy transition goals for total decarbonisation by 2050 Greece[3], as member of the European Union has to abide. In the European Commission's "Clean Energy for All Europeans" strategy natural gas is considered to be a bridge fuel that can aid in the transition to renewable energy, because, as it is literally mentioned in the official texts, *gas plants can be easily fired up and down unlike other types of plants, and gas emits 50% less carbon dioxide than coal when burnt* (European Commission 2016).

EU's persistent focus on supply of commodities such as natural gas - a commodity the many proponents of renewals strictly reject- is understandable. After a temporary sharp decrease in the consumption of natural gas in 2020 due to the economic decline, caused by the corona pandemic, the natural gas share in the EU's energy consumption continued to grow in 2021 as many EU-countries started implementing their carbon-neutral energy policy and Germany is set to shut down its last nuclear power plants by the end of 2022. Since the gas price[4] has spiked, electricity costs around Europe have also skyrocketed, despite the fact gas only accounts for 18-20 percent of the EU's electricity mix. The increased consumption, combined with the decrease in the EU's gas production, will further increase the EU's gas import dependence. In 2020, over 85 percent of gas consumed in the EU was imported from outside the Union. The share of natural gas has increased particularly rapidly in Greece, Portugal and Spain (Liuhto, 2022, pp. 21-60). Therefore, the EU has disbursed millions of euro for feasibility studies in natural gas related projects in the Eastern Mediterranean.

[3] In December 2019, the Greek government announced the very ambitious National Plan for Energy and Climate that, in some cases, set even higher goals than the European Green Deal. The ending of Greece's reliance on lignite (the main domestic energy source) is scheduled to be achieved by 2028 and renewable energy sources (RES) are projected to reach the 65% of electricity production in 2030, becoming the main national energy source in Greece. https://greeknewsagenda.gr/topics/politics-polity/7126-greece%E2%80%99s-green-agenda-on-energy-and-climate.

[4] Gas is predominantly priced using two mechanisms: 1) oil price indexation, or oil price escalation, where the value of gas is determined based on the price dynamics of oil products, and 2) market-based pricing where gas prices are set through the interaction between gas supply and demand (). Gas producers and infrastructure operators will only generate a profitable return when their assets are used at a reasonable rate of throughput and at revenues that cover their costs over the longer term. They need security of demand. The consumers, by investing in specific gas-fired infrastructure, are committed to using gas and hence they need security of supply. Accordingly, as far as consumption is concerned, states are interested in access to energy, preventing disruptions and reducing price volatility. As far as production is concerned, states are interested in selling enough raw materials to provide economic welfare (Correljé, 2016: 29; Chyong, 2016: 41-62).

However, the EU policy in this regard began to change recently. In February 2021, the European Commission announced the *New Agenda for the Mediterranean*, which will guide the EU's policy towards the region and the multi-annual programming under the *EU's new Neighbourhood, Development and International Cooperation Instrument* at the regional and bilateral levels. The new agenda encourages member states and southern neighbourhood partners to join forces in fighting climate change and speeding up the twin green and digital transition. Among other policy areas it focuses on the green transition, climate resilience, energy, and environment with a view of taking advantage of the potential of a low-carbon future, protect the region's natural resources and generate green growth. The new agenda, as it is the case with the European Green Deal as well, also promises to spur investment and public-private partnerships to promote socio-economic sustainability in Europe's southern neighbourhood (EU Commission 2021).

The driving force behind this change is the climate crisis unfolding in the Eastern Mediterranean in full display. As fossil fuels still account for 80 percent of the global energy mix, energy consumption remains closely related to greenhouse gas emissions and hence to climate forcing. Climate change is a particularly pressing threat for the Mediterranean and is shared by all states of this region, irrespective of their present socio-economic or political standing (Dessì/Fattibene/Fusco, 2021, pp. 16-17).

Indeed, while frictions among the countries of the region about maritime zones and continental shelf claims abounded in recent years nearly provoking large-scale conflicts, the impact of the climate crisis on the same countries has been extreme, especially in 2021, when Greece and Turkey battled record-breaking blazes. The Mediterranean's more than half-a-billion inhabitants seem to face highly interconnected climate risks. The Mediterranean basin is perceived to be particularly vulnerable to the interconnected challenges stemming from climate change and environmental degradation. Reasons for concern include sea-level rise related risks, land and marine biodiversity losses, risks related to drought, wildfire, alterations of water cycle, endangered food production, health risks in both urban and rural settlements from heat and altered disease vectors. Temperatures are going up 20% faster than the global average and this is already having real and serious consequences across the basin with sea level rises expected to exceed one metre by 2100, impacting one third of the population in the region (WWF Mediterranean Marine Initiative, 2021).

The UN Intergovernmental Panel on Climate Change has labelled the region as a 'climate change hotspot' expecting the warming across the Mediterranean to be about 20 percent higher than global averages in the decades to come, as the region is hit with devastating heatwaves, which in turn trigger water shortages, loss of biodiversity and risks to food production. According to the report an increase of 10-20 days per year of maximum daily temperature exceeding 35°C, a typical, critical threshold for crop productivity and analogous increase in agricultural, ecological and hydrological droughts is expected, by the mid-century, in the Mediterranean areas. Moreover, streamflow droughts and fire weather conditions are projected to become more severe and persistent in the region (United Nations 2021).

For several years, it was generally believed that, since natural gas has the lowest carbon dioxide emissions among fossil fuels, the 'obvious' way to reduce carbon emissions was to switch from other fossil fuels to natural gas. In particular, industry groups sometimes refer to natural gas as clean energy, since it produces less carbon dioxide and far fewer air pollutants than coal does when burned. in the power generation sector, switching from coal to gas was seen, with some justification, to yield significant CO2 savings. In the framework of the goal of achieving carbon-neutrality by 2050, however, continuing to burn significant quantities of fossil-derived natural gas appears not be sustainable (Lambert 2018). Though it is cleaner than oil, natural gas is still a fossil fuel. It is the source of methane emissions that is considered to be more powerful

greenhouse gas than carbon dioxide, while the hydraulic fracturing process also involves the use of harmful chemicals. Natural gas still produces far more carbon than wind, solar or nuclear power. Up to now, hydrogen has mostly been obtained from natural gas and only very little hydrogen has been produced with renewable energies. Therefore, the conventional hydrogen causes CO2 emissions and it is unsuitable for the green transition in the long term.

Beyond that, environmental organisations and local groups are opposed to the plans for extraction of new oil and gas. Many energy experts are heavily questioning the overall utility of the extraction of hydrocarbons in Greece due to the potential environmental hazards. They also warn of costs associated with oil and gas extraction, which may lead to economic loss, since the overwhelming majority of tourism and recreation activities take place near the coast. The economic impacts of an oil spill on industries connected to the marine environment, e.g. the fishing and tourism industries is also linked to the environmental impact on commercially viable species and the aesthetic impacts of an oil spill. In this respect, they argue that any profits from the oil exploration activities will largely be reaped by the hydrocarbon companies, whereas the benefits to citizens will be minimal, as oil and gas will remain at the same prices set by international stock exchanges (Archipelagos Institute of Marine Conservation 2019).

They argue that the planned extraction of hydrocarbon deposits poses a dramatic risk of irreversible ecological and socio-economic disaster both within the marine regions and productive land zones where explorations are designed to take place, as well as for the country as a whole. Incidents can occur at various steps of the production process, including transportation of products by ships and the extraction process itself, for example from damaged installations resulting from explosions. According to the same argumentation, the reserves to be exploited are relatively small, however the drilling is of particular concern, given the large depth associated with the offshore fields as well as the seismic activity in the area, resulting in a logistically and technically challenging operation. Inevitably those activities will increase the environmental impacts with different characteristics: direct and indirect, short and long term, temporary and permanent, singular and cumulative (Economists for the environment, 2019).

REFERENCES

Agalliu Irena, Montero Aube, Adams Stephen, Gallagher Shawn (2018). *Comparative Analysis of the Federal Oil and Gas Fiscal Systems: Gulf of Mexico International Comparison*. Study for U.S. Department of the Interior Bureau of Ocean Energy Management, Bureau of Safety and Environmental Enforcement, Bureau of Land Management.

Agbaeze, E.K, Ukoha, Kalu (2018). Oil a Blessing or a Curse: The Nigerian Experience. *European Journal of Social Sciences*, 56 (3): 262-270.

American Petroleum Institute (2017). Impacts of the Natural Gas and Oil Industry on the US Economy in 2015. Report. Available from http://www.api.org/~/media/Files/Policy/Jobs/Oil-and-Gas-2015-Economic-Impacts-Final-Cover-07-17-2017.pdf

Archipelagos Institute of Marine Conservation (2019). Potential hydrocarbon exploration in Greece, will Blue or Black Growth be the choice? Report. Available from http://archipelago.gr/en/potential-hydrocarbon-exploration-greece-will-blue-black-growth-choice/

Aslanli Kenan (2015). Fiscal sustainability and the State Oil Fund in Azerbaijan. *Journal of Eurasian Studies*, 6: 114-121.

Aslani Alireza, Hamlehdar Maryam and Saeedi Reza, Robustness of Norway Economy and Energy Supply/Demand, International Journal of Green Computing, vol. 8, issue: 2 (2017).

CASPINFO: http://www.caspinfo.net/content/content.asp?menu=0120000_000000

Chi-Kong Chyong (2016). On the Future of Global LNG Trade and Geopolitics, in: Silvia Colombo, Mohamed El Harrak and Nicolò Sartori (eds.), *The Future of Natural Gas Markets and Geopolitics*. The Netherlands: Lenthe/European Energy Review.

Ciarreta Aitor, Nasirov Shahriyar (2012). Development trends in the Azerbaijan oil and gas sector: Achievements and challenges. *Energy policy*, 40: 282-292.

Colgan JD (2014). Oil, Domestic Politics, and International Conflict. *Energy Research & Social Science*, 1: 198-205. Available from http://dx.doi.org/10.1016/j.erss.2014.03.005.

Correljé Aad (2016). The European Natural Gas Market. *Curr Sustainable Renewable Energy Rep*, 3, 28–34. Available from https://doi.org/10.1007/s40518-016-0048-y

Azhgaliyeva Dina (2014). The effect of fiscal policy on oil revenue fund: The case of Kazakhstan. *Journal of Eurasian studies*, 5: 157-183.

Dessì Andrea/Fattibene Daniele/Fusco, Flavia (2021). Mediterranean Transitions: The Challenge of Sustainable Development', in Andrea Dessì, Daniele Fattibene and Flavia Fusco (eds), *Climate change and sustainability: Mediterranean perspectives.* Rome: Rome Edizioni Nuova Cultura for Istituto Affari Internazionali.

Economists for the environment-EFTEC, Economic impacts of the exploitation of hydrocarbons in Greece. An analysis for World Wide Fund for Nature (WWF) – Greece (January 2019).

Engel Rozlyn (2013). Managing newfound hydrocarbon wealth macroeconomic policy challenges in the Eastern Mediterranean. The German Marshall Fund of the United States, Mediterranean paper series.

European Commission - Press release, (30 November 2016), "Clean Energy for All Europeans - unlocking Europe's growth potential". Available from http://europa.eu/rapid/press-release_IP-16-4009_en.htm.

EU Commission Press release (9 February 2021). Southern Neighbourhood: EU proposes new Agenda for the Mediterranean'. Available from https://ec.europa.eu/commission/presscorner/detail/en/ip_21_426.

Frankel Jeffrey (2010). The Natural Resource Curse: A Survey. *HKS Faculty Working Paper*.

Franza Luca (2021). Greening the Mediterranean: Pathways for Sustainable Energy and Climate Cooperation. In: Andrea Dessì, Daniele Fattibene and Flavia Fusco (eds), *Climate change and sustainability: Mediterranean perspectives*. Rome: Rome Edizioni Nuova Cultura for Istituto Affari Internazionali.

Hemmings Philip (2018). Norway's economy: maintaining a successful business sector in a changing world, *OECD Working papers*. No. 1459.

Homer-Dixon (1999). *Environment, Scarcity, and Violence*. New Jersey: Princeton University Press.

Huliaras, Asteris and Sotiropoulos Dimitri A. (2018). The crisis in Greece: The semi-rentier state hypothesis', Hellenic Observatory Papers on Greece and Southeast Europe, No.120.

King, C. (2012). The Scottish play: Edinburgh's quest for independence and the future of separatism', *Foreign Affairs*, 91: 2–15.

Lambert, Martin (2018). The Power-to-Gas: Linking Electricity and Gas in a Decarbonising World? Oxford Institute for Energy Studies papers, *Oxford Energy Insight*, 39.

Litvinenko Vladimir (2020). The Role of Hydrocarbons in the Global Energy Agenda: The Focus on Liquefied Natural Gas. *Resources*, 9; doi:10.3390/resources9050059

Liuhto Karl (2022). Natural gas in the EU in the 21st century: A special emphasis on LNG. In: Kari Liuhto (ed.), *The Future of Energy Consumption, Security and Natural Gas*. Switzerland AG Springer Nature.

Mahdavy Hossein (1970). The Pattern and Problems of Economic Development in Rentier States: The Case of Iran. In M.A. Cook (Ed.), *Studies in the Economic History of the Middle East*. Oxford: Oxford University Press.

Mezartasoglou Dimitris/Stambolis Costis/Perellis Alexandros/ Koutroumbousis Alexandros (2020). *The Greek Energy Sector - Annual Report 2020*. Institute of Energy for SE Europe (IENE).

Mingst Karen (2008). *Essential of International Relations*. Fourth Edition, New York and London: W.W. Norton and Company.

Oikonomopoulos Kostis 2020 (ed.), *Hydrocarbon Exploration in Greece: The role of Hellenic Hydrocarbons Resources Management,* Hellenic Hydrocarbons Resources Management SA Study. https://www.greekhydrocarbons.gr/news_files/hhrm_book_2020_eng.pdf (accessed August 2021).

Palasciano Andrea (2019). Seals, caviar and oil: Caspian Sea faces pollution threat. phys.org, 16. Available from https://phys.org/news/2019-04-caviar-oil-caspian-sea-pollution.html

Pomfret Richard (2012). Resource management and transition in Central Asia, Azerbaijan and Mongolia. *Journal of Asian Economics*, 23: 146-156.

Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) (2021). MEDITERRANEAN ACTION PLAN. Fourteenth Meeting of the Focal Points of the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea. Online, 31 May – 2 June 2021. https://www.rempec.org/en

Sachs, Jeffrey, and Warner Andrew (1995). Natural Resource Abundance and Economic Growth. *NBER Working Paper* 5398.

Satpayev Dossym and Umbetaliyeva Tolganay (2015). The protests in Zhanaozen and the Kazakh oil sector: Conflicting interests in a rentier state. *Journal of Eurasian Studies*, 6: 122-129.

Scholten Daniel (2018). The Geopolitics of Renewables—An Introduction and Expectations. In: D. Scholten (ed.), *The Geopolitics of Renewables*. Switzerland AG: Springer International Publishing.

Sovacool Benjamin (2021). Clean, low-carbon but corrupt? Examining corruption risks and solutions for the renewable energy sector in Mexico, Malaysia, Kenya and South Africa. *Energy Strategy Reviews*, 38(5). Available from 100723. DOI: 10.1016/j.esr.2021.100723

Steans Jill and, Pettiford Lloyd with, Dietz Thomas (2005). *Introduction to International Relations. Perspectives and Themes*. Second edition, Harlow-England: Pearson.

Stergiou Andreas (2017). Energy Wealth as Peace and Democracy Incentive: The Eastern Mediterranean Case. In: George C. Bitros, Nicholas C. Kyriazis (eds), *Democracy and an Open-Economy World Order*. Switzerland: Springer International Publishing.

The Greenland home rule government Bureau of Minerals and Petroleum (2004). *Report on socio-economic aspects of hydrocarbon exploration and exploitation in Greenland*. Available from https://naalakkersuisut.gl/~/media/Nanoq/Files/Publications/Raastof/DK/Report%20on%20socio-economic%20aspects%20of%20hydrocarbon%20exploration%20and%20exploitation%20in%20Greenland.pdf

The World Bank (2011). *Sustainable Energy Department, Issues in estimating the employment generated by energy sector activities*.

Tsani, Stella (2013). Natural resources, governance and institutional quality: The role of resource funds. *Resources Policy*: 181-195.

United Nations Environment Programme (2013), *MEDITERRANEAN ACTION PLAN*. 1st Offshore Protocol Working Group Meeting Valletta, Malta, 13-14 June 2013. https://www.rempec.org/en

United Nations (2021), *Intergovernmental panel on climate change*, full report. Final Government Distribution https://www.ipcc.ch/report/ar6/wg1/#FullReport.

Van den Bremer Ton/Van der Ploeg Frederick/ Wills Samuel (2016). The Elephant in the Ground: Managing Oil And Sovereign Wealth. *European Economic Review*, 82: 113-131.

VanDeveer Stacy (2013). Still Digging: Extractive Industries, Resource Curses, and Transnational Governance in the Anthropocene. *Transatlantic Academy Paper Series*. Washington: German Marshall Fund.

WWF Mediterranean Marine Initiative (2021). The climate change effect in the Mediterranean. Six stories from an overheating sea. Available from https://wwfeu.awsassets.panda.org/downloads/final_wwf_med_cc_6_case_studies_2021.pdf

Yergin Daniel (2011). *The Quest. Energy security and the remaking of the Modern World*, New York: The Penguin Press.

Zulfigarova Farid and Neuenkircha Matthias (2020). The impact of oil price changes on selected macroeconomic indicators in Azerbaijan. *Economic Systems*, 44(4), doi: 10.1016/j.ecosys.2020.100814

PWYP INDONESIA (2021). Understanding the Onshore and Offshore Schemes in the Upstream Oil and Gas Industry', *IN BLOG*. Available from https://pwypindonesia.org/en/understanding-the-onshore-and-offshore-schemes-in-the-upstream-oil-and-gas-industry/

Uncertainty effects and environmental determinants of Bitcoin's price crash risk during the COVID-19 pandemic

Nikolaos A. Kyriazis
Department of Economics, University of Thessaly, Volos, Greece
knikolaos@uth.gr

Abstract
This paper investigates the determinants of Bitcoin price crash risk during the first two waves of the COVID-19 pandemic. High-frequency (1-minute) data are employed in order to set under scrutiny Bitcoin return volatility. Focus is made on the impacts of economic policy uncertainty, geopolitical risk, investor sentiment, fluctuations in stock markets and MSCI and FTSE environmental indices on abrupt downwards movements regarding Bitcoin's market values. Univariate and multivariate regressions result into a spectrum of fruitful results about the impacts of uncertainty and environmental indices on cryptocurrency instability. This study provides a roadmap for investors interested in modern financial assets during turbulent eras in an economic and environmental context.

Keywords: Bitcoin price crash. Economic policy uncertainty, Geopolical Risk, Investor sentiment, Environmental impacts

JEL Codes: F64; F65; G12; G15; Q51.

Strategic spatial planning of fire resources for the protection of natural and built environment from wildfires in the light of climate change

Stavros Sakellariou[1]*, Olga Christopoulou[1] and Sophoclis Dritsas[2]

[1] *Department of Planning and Regional Development, University of Thessaly, 38334 Volos, Greece*

[2] *Department of Ichthyology & Aquatic Environment, University of Thessaly, 38334 Volos, Greece*

stasakel@uth.gr, ochris@uth.gr, dritsas@uth.gr

Abstract

Wildfires are a natural phenomenon but may potentially be transformed to environmental hazard that can have serious consequences for natural and anthropogenic ecosystems. Future projections predict that, under a climate change environment, the fire season (especially in Southern Europe) will be lengthier, with higher levels of droughts leading to higher fire severity. Therefore, critical time of response for initial attack constitutes the basis for effective and timely fire management. The aim of the paper focuses on the establishment of optimal location options for initial attack based on burn probability as well as on population capacity (*Wildland Urban Interface*). Several spatial schemes of optimal locations were developed considering the ideal and realistic critical time of response (2 scenarios), as well as the current and desired capacity of the fire service. Hence, the proposed Spatial Decision Support System would significantly enhance the fire agency's capabilities taking into account the maximization of environmental protection and the rationalization of financial resources.

Keywords: wildfires; burn probability; population capacity; initial attack; spatial optimization.

JEL Classification: Q23; R41; R58.

1. Introduction

Wildfires are a natural phenomenon but may potentially be transformed to environmental hazard that can have serious consequences for natural and anthropogenic ecosystems (Badia et al., 2019; Sakellariou et al., 2017; 2021). Future projections predict that, under a climate change environment, the fire season (especially in Southern Europe) will be lengthier, with higher levels of droughts leading to higher fire severity (EEA, 2021).

Therefore, the critical time of response constitutes the key to effective and timely forest fires management (ESRI, 2007). In Mediterranean countries, most fire ignitions are immediately confronted, as the risk of fires expansion to ecological and / or cultural / historical sites is very high. This happens mainly due to the spatial structure of the housing network, infrastructure and biophysical characteristics of these areas (Morehouse et al., 2011). However, many wildfires occur in the Wildland Urban Interface (WUI), which is a common feature worldwide (Cohen, 2010; Syphard et al., 2008).

Burn probability estimation constitutes a critical input for wildfires prevention. Burn probability maps have been used to determine the most susceptible regions (Parisien, 2005; Shang et al., 2020) for optimizing the wildfires management and prevention (Stockdale et al., 2019). In the same context, location-allocation analysis has been widely used for emergency situations. This type of analysis permits the selection of best locations for immediate response (e.g. fire brigade services) or approach (e.g. ambulance approach). Hence, effective spatial models have been developed to maximize the demand coverage (Alexandris and Giannikos, 2010; Matisziw and Murray, 2009; Sakellariou et al., 2020) based on the Church and Velle (1974) *Maximal Coverage Location Problem*.

Consequently, by utilizing spatial optimization techniques (Alexandris and Giannikos, 2010; Farhan and Murray, 2006; Liu et al., 2006; Matisziw and Murray, 2009; Murray and Tong, 2009), primary aim of the paper constitutes the selection of the optimal number and locations for fire resources next to water tanks based on fire vulnerability and population capacity of towns (WUI).

2. Methods and Data

The methodology of the paper is based on the combination of wildfires simulation modeling and operations research. The burn probability map highlights the most vulnerable regions which need further attention. This input has been used in the network analysis which tries to minimize the travel time from any potential location (i.e. any water tank) to the most susceptible regions. Hence, the areas which are at highest risk “attract” the fire resources, so that these forces can approach these regions the soonest possible.

3.1 Data

The primary data used consist of statistical and geospatial data. The statistical data primarily consist of fire history data (e.g. historical fire frequency; time-series fire weather data etc.), feeding the reliability of wildfires simulation modeling. The geospatial data consist of forest fuels, the locations and population of inhabited regions as well as the locations of fire resources (i.e. current location of fire agency and water tanks). Finally, the road network geodatabase is used for the estimation of travel time from the fire resources to any potential fire hot spot.

3.1.1 The case of Thasos island

Thasos island is located in the north-eastern part of Greece and constitutes an island than administratively belongs to Prefecture of Kavala. The geographical coordinates are: Latitude: 40°41′N; Longitude: 24°39′E.

3.2 Methods

The cornerstone of the methodology lies in the interaction of wildfires simulation modeling and the spatial optimization of the potential locations for immediate response in any fire ignition. Initially, the burn probability of each pixel is computed, so that we can estimate the fire vulnerability of each part of the study area. The burn probability considers the fire history through fire ignition and fire environment submodules (i.e. historical patterns of fire ignitions -fire frequency; size and length of fire events-; fire weather features -time series analysis of fire weather index per day; simulation of wind-driven wildfires in synergy with topography) as well as the fire simulation parameters which are relative to vegetation phenology. The climate change impacts have been integrated through the long-term evolution of fire weather index. The higher the fire weather index, the higher the expected fire severity.

Having estimated the burn probability for each area of the study domain, the spatial optimization process took place based on two primary hypotheses. The first one is related with the finding of best positions of fire resources for immediate response based on fire vulnerability magnitude. The fire vulnerability magnitude is depicted in Table 1. The more times each pixel is burned in the simulation, the larger weight receives (i.e. quite susceptible regions). The second part of the analysis is related with the finding of best positions of fire resources for immediate response based on population size, primarily focusing on the WUI. Here, the higher the population size the larger weight receives (i.e. the most populated towns concentrate higher possibilities of fire ignitions due to the presence of multiple socioeconomic activities).

Table 1: Classification and weight of each pixel per fire vulnerability level

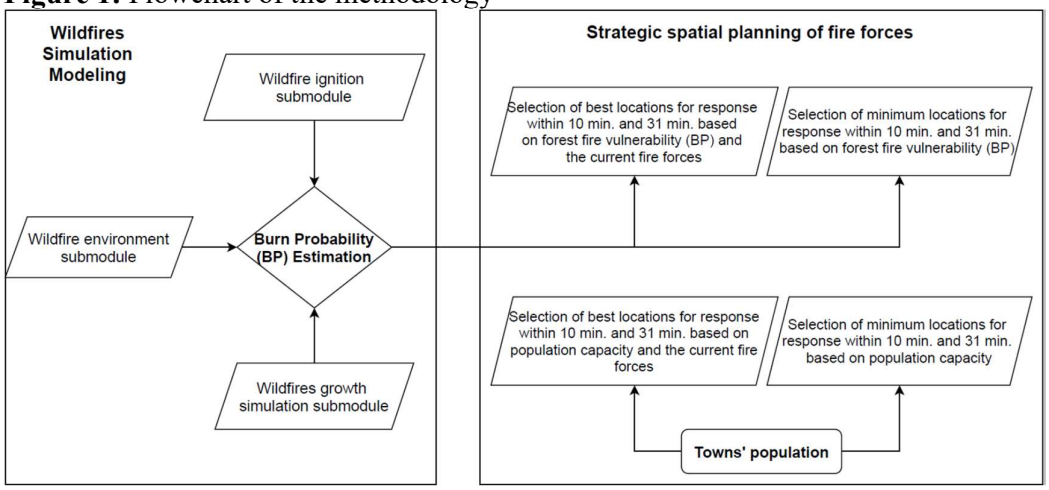
Classification per number of fire ignitions (Natural Breaks – Jenks)	**Weight per fire vulnerability level**	**Weight per population level**
0 – 639	1: Very low	1: < 158
640 – 1.236	2: Low	2: 159 – 452
1.237 – 1.881	3: Moderate	3: 453 – 815
1.882 – 2.633	4: High	4: 816 – 1.383
2.634 – 3.764	5: Very high	5: > 1.384

Next, the simulation scenarios incorporate differentiated situations. First, we examined the immediate response taking place within 10 min. (ideal scenario) and 31 min. (realistic scenario). 31 min. is the average response time for the entire Prefecture.

Finally, two additional hypotheses are taken into consideration. Specifically, we developed differentiated spatial schemes of fire resources for all scenarios based on current fire forces (10 fire vehicles) as well as based on the minimum required fire forces to achieve the maximization of geographical coverage. It should be noted that we try to find the 8 best locations across the island given that 2 fire vehicles should always be located in the capital of the island for any other case beyond fires.

Figure 1 summarizes all the above processes, from burn probability estimation to strategic spatial planning of fire resources according to the hypotheses taken for each scenario.

Figure 1: Flowchart of the methodology



4. Empirical Results and Discussion

This section describes the results of wildfires simulation modeling (i.e. fire vulnerability map) and the differentiated spatial schemes of fire resources for each scenario.

Figure 2 presents the burn probability estimation in Thasos island. We observe that the southern part of the island has been at the greatest risk, where few inhabited regions exist. This part is characterized by abundant and flammable forest fuels. The remaining territory of the island is characterized by low or moderate risk.

Figure 3 depicts the location schemes of fire resources based on fire vulnerability for different time response. The analysis with 10 min. time response (Figure 3a) indicates the selection of 6 over 8 positions in the central and southern part of Thasos where the fire susceptibility is higher. Just two locations are recommended in the northeast where the fire vulnerability can be considered of moderate degree.

Figure 2: Burn probability estimation in Thasos island

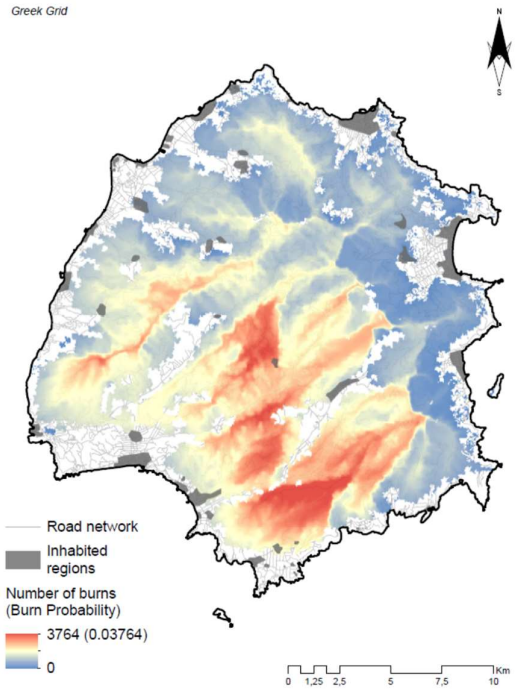
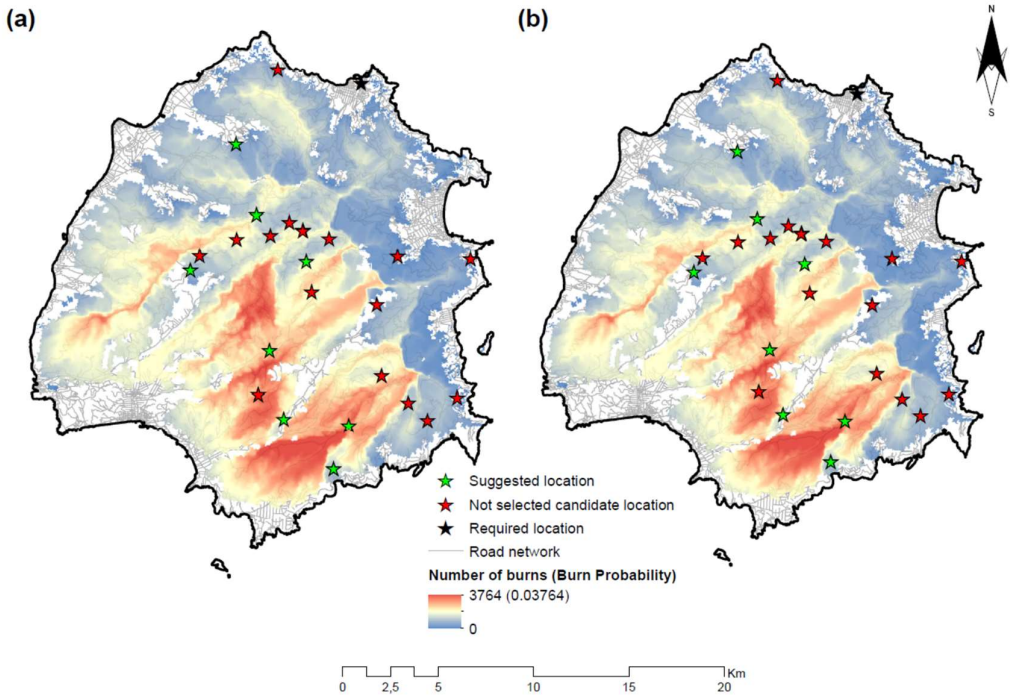


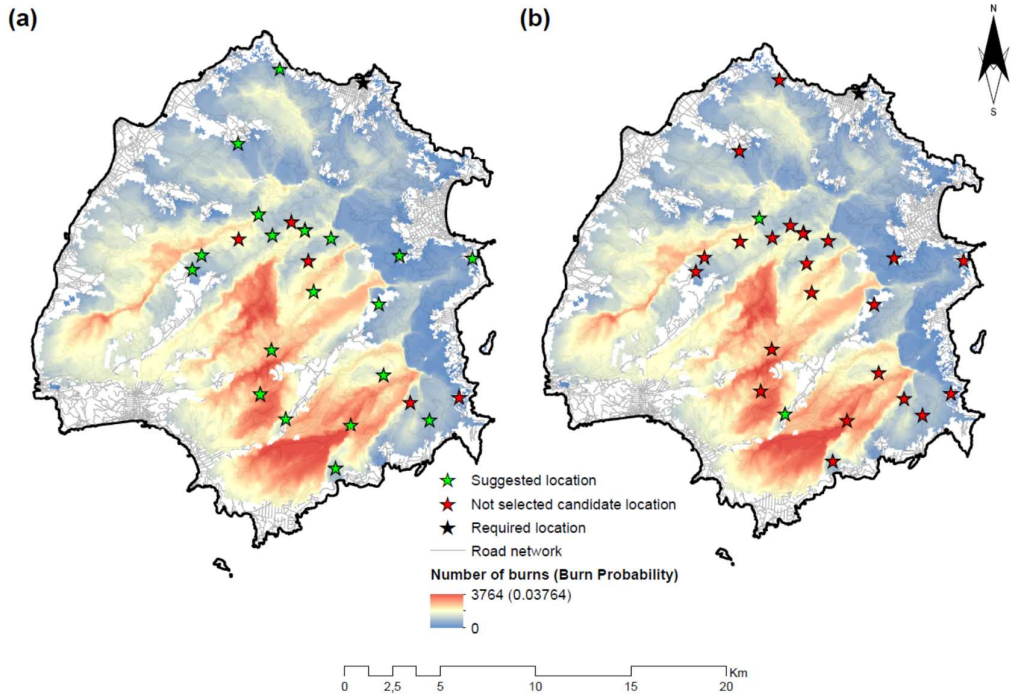
Figure 3: Selection of best locations for response within (a) 10 min. and (b) 31 min. based on forest fire vulnerability



The same pattern appeared when we adopted the analysis with 31 min. time response (Figure 3b). This fact demonstrates that these locations are the most effective when we examine the interrelation of the current fire forces and the fire vulnerability.

Figure 4 shows the minimum number and locations of fire resources to achieve the maximization of geographical coverage for both scenarios. With response within 10 min., we would need additional 11 fire vehicles to effectively cover the most susceptible regions in this time frame. Hence, we realize that the 8 current fire vehicles are not enough for immediate response. So, 19 recommended positions are considered adequate for response within 10 min. for the entire island. On the contrary, when we adopt the scenario with response within 31 min., we see that we only need two locations to primarily cover the most vulnerable regions. One can be found in the south and one in the north covering the two halves of the island within this time frame.

Figure 4: Selection of minimum locations for response within (a) 10 min. and (b) 31 min. based on forest fire vulnerability



The next stage of analysis focuses on the population capacity of each town. Now, the selection of best positions next to water tanks considers the population magnitude for immediate response. Figure 5 depicts the most efficient locations which maximize the geographical coverage of towns (i.e. the majority of the most populated towns) within 10 and 31 min. respectively. In Figure 5a, we observe the best 8 positions for response within 10 min., situated at all the sides of the island. However, there are a few towns exposed in the western part of the island because there is no any optimal location at which the fire vehicles can approach these towns within this time frame. On the contrary, when we adopt the time response within 31 min. (Figure 5b), the spatial scheme of fire resources is slightly changed, covering all the inhabited regions. Now, the fire vehicles can reach any town in less than 31 min by the 8 suggested locations.

Figure 5: Selection of best locations for response within (a) 10 min. and (b) 31 min. based on population capacity (WUI fires)

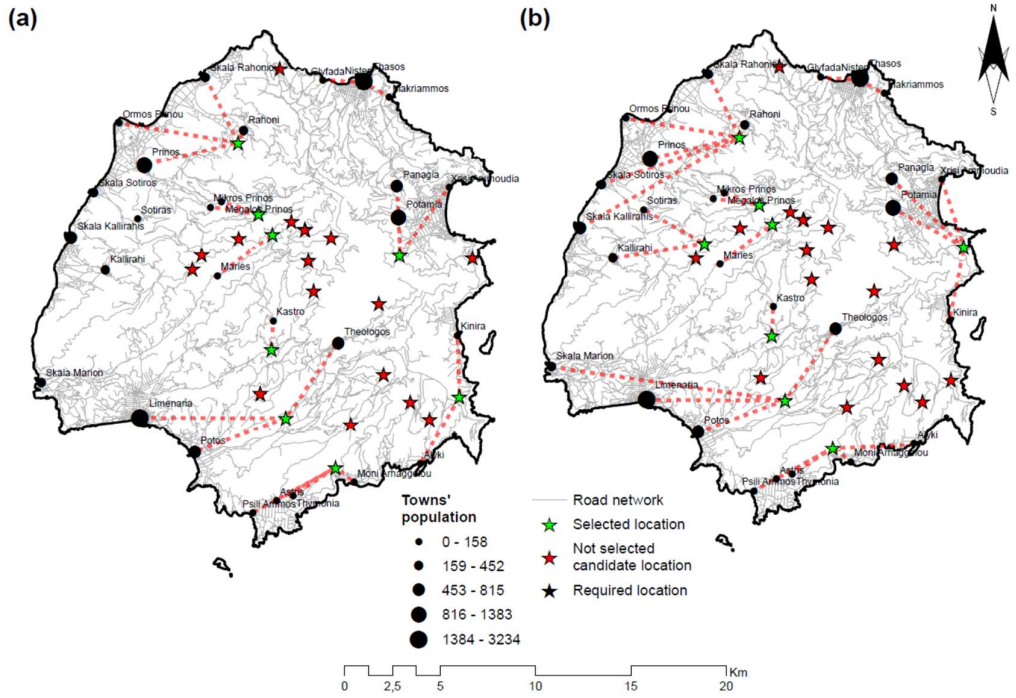
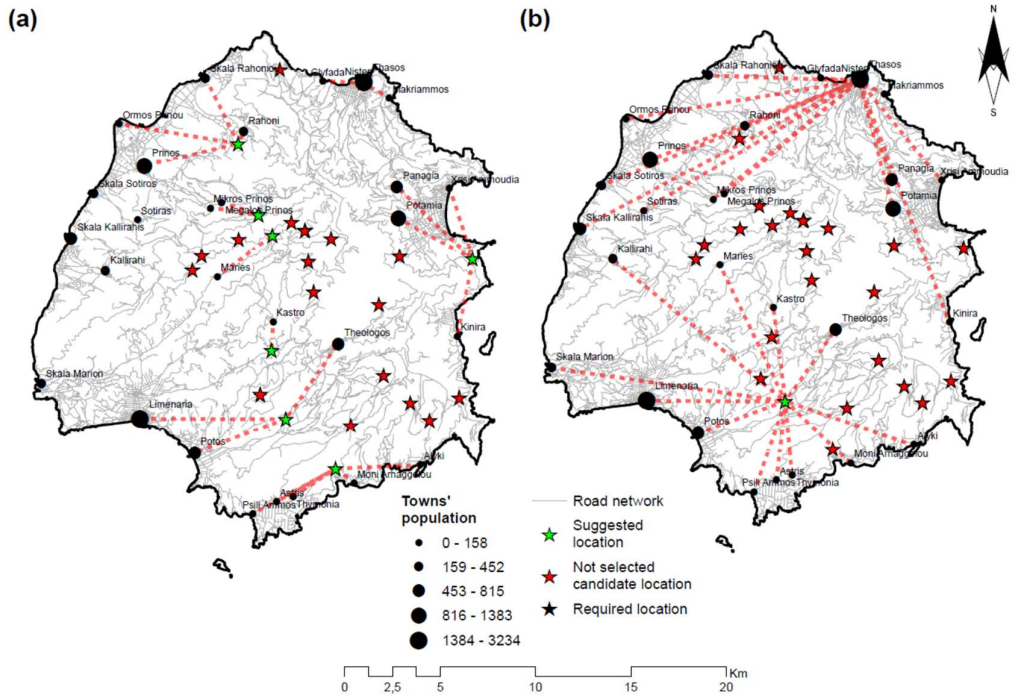


Figure 6: Selection of minimum locations for response within (a) 10 min. and (b) 31 min. based on population capacity (WUI fires)



Finally, the spatial scheme of the proposed locations is differentiated when we try to minimize the supply of fire resources. We observe the distribution of 7 locations covering the entire area of the island, except the western towns (Figure 6a). Again, there is no any location that a fire

vehicle can reach any of these towns within 10 min. That is why, the 7 positions are considered adequate meeting the same level of environmental protection. On the other side, the fire agency at the capital of the island and one more position in the south, are considered adequate to cover all the towns within 31 min. taking the corresponding environmental risk of the late response.

5. Conclusions

Wildfires prevention is of utmost importance for the protection of natural and built environment. Hence, efficient preventative measures and tactics should be implemented. The conjunction of simulation modeling and operations research could provide solutions from environmental and financial perspective. In this paper, the estimation of burn probability through simulation modeling provided the background of fire susceptibility for the entire island. Based on the current and minimum required resources for immediate response, we developed differentiated spatial schemes of fire vehicles according to ideal (10 min.) and realistic (31 min.) time of response. These location schemes considered both the fire vulnerability and population size for the optimal allocation of fire forces. We concluded that the fire forces (8 + 2 vehicles) are adequate only when we adopt the longer time of response (i.e. 31 min.). When we need maximum environmental protection adopting the least possible time of response (i.e. 10 min.), additional forces are required. Hence, the selection of any location scheme of fire resources could lead either to maximization of environmental protection with high level of investment or to lower environmental protection with a financial rationalization of fire resources. The final selection of any location scheme could be dictated by the projected weather conditions which tend to be more favorable for higher fire severity due to increasing climate change effect.

References

Alexandris G. and Giannikos I., 2010. A new model for maximal coverage exploiting GIS capabilities. *European Journal of Operational Research* **202**(2): 328:338.

Badia A., Pallares:Barbera M., Valldeperas N., and Gisbert M. (2019). Wildfires in the wildland:urban interface in Catalonia: Vulnerability analysis based on land use and land cover change. *Science of the total environment*, 673: 184:196.

Church R. and Velle C.R., 1974. The maximal covering location problem. *Papers in regional science* **32**(1): 101:118

Cohen J., 2010. The wildland:urban interface fire problem. *Fremontia* **38**(2:3): 16:22.

EEA (2021). European Environment Agency: *Forest fires in Europe*. Available from: https://www.eea.europa.eu/ims/forest:fires:in:europe

ESRI, 2007. GIS for fire station locations and response protocol. An ESRI White Paper. 28p. Available from: https://www.esri.com/~/media/Files/Pdfs/library/whitepapers/pdfs/gis:for:fire.pdf

Farhan B. and Murray A.T., 2006. Distance decay and coverage in facility location planning. *The Annals of Regional Science* **40**(2): 279:295

Liu N., Huang B. and Chandramouli M., 2006. Optimal siting of fire stations using GIS and ANT algorithm. *Journal of computing in civil engineering* **20**(5): 361:369.

Matisziw T.C. and Murray A.T., 2009. Siting a facility in continuous space to maximize coverage of a region. *Socio:Economic Planning Sciences* **43**(2): 131:139

Morehouse B.J., Henderson M., Kalabokidis K. and Iosifides T., 2011. Wildland fire governance: perspectives from Greece. Journal of Environmental Policy & Planning 13(4): 349:371.

Murray A.T. and Tong D., 2009. GIS and spatial analysis in the media. *Applied geography* **29**(2): 250:259.

Parisien M.-A., Kafka V.G., Hirsch K.G., Todd B.M., Lavoie S.G. and Maczek P.D., 2005. Mapping fire susceptibility with the Burn-P3 simulation model. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta, Information Report NOR-X-405.

Sakellariou S., Sfougaris A., and Christopoulou, O. (2020). Location Planning of Fire Service Fleet Based on Forest Fire Susceptibility. *WSEAS Transactions on Environment and Development*, *16:* 643-648.

Sakellariou S., Sfougaris A., and Christopoulou O. (2021). Review of Geoinformatics:Based Forest Fire Management Tools for Integrated Fire Analysis. *Polish Journal of Environmental Studies*, 30(6): 5423:5434.

Sakellariou S., Tampekis S., Samara F., Sfougaris A., and Christopoulou O. (2017). Review of state:of:the:art decision support systems (DSSs) for prevention and suppression of forest fires. *Journal of Forestry Research*, 28(6): 1107:1117.

Shang, C., Wulder, M. A., Coops, N. C., White, J. C., & Hermosilla, T. (2020). Spatially:Explicit Prediction of Wildfire Burn Probability Using Remotely:Sensed and Ancillary Data. *Canadian Journal of Remote Sensing*, *46*(3), 313:329.

Stockdale, C., Barber, Q., Saxena, A., & Parisien, M. A. (2019). Examining management scenarios to mitigate wildfire hazard to caribou conservation projects using burn probability modeling. *Journal of environmental management*, *233*, 238:248.

Syphard A.D., Radeloff V.C., Keuler N.S., Taylor R.S., Hawbaker T.J., Stewart S.I. and Clayton M.K., 2008. Predicting spatial patterns of fire on a southern California landscape. *International Journal of Wildland Fire* **17**: 602–613

Consumer perceptions for bioplastics: Notes from the field

Skouloudis Antonis[1], **Panagiotopoulou Altani**[2] & **Lekkas Demetris-Francis**[1]
[1] Dep. of Environment, University of the Aegean,
[2] Dep. of Marketing & Communication, Athens University of Economics & Business
skouloudis@aegean.gr, *apanagiotopoulou@aueb.gr*, *dlekkas@aegean.gr*

Abstract
This study explores consumer reactions to bioplastic products. Utilizing qualitative data drawn from personal interviews with potential consumers of bioplastics, we attempt to shed light on consumer viewpoints and thoughts that shape perceptions and attitudes towards the emerging bioplastics industry. Findings reveal that interviewees generally have a positive attitude towards these new bio-based materials with certain issues around the intrinsic characteristics of these products. Such findings have the potential to provide theoretical and managerial implications. From a theoretical perspective, qualitative results such as those reported in the study contribute to the consumer behavior over green products literature shedding light on how individuals understand, interpret, feel, and/or react to bio-based plastics. From a managerial standpoint, the study offers fruitful insights to new product development and communication under the scope of consumers' expectations, stimulating managers to focus on actions towards more effective product marketing strategies and environmentally responsible practices that may enhance business efficiency, productivity and/or market share.

Keywords: Plastics; bio-based plastics/bioplastics; consumer attitudes-perceptions; purchase intentions; Greece.

Introduction

A substantial amount of research over the past decades has focused on the impacts of plastics on the environment and human health (Storz and Vorlop, 2013; De Marchi et al., 2020; Chen and Tan, 2021). Indeed, plastics are considered an integral part of modern lifestyle due to their characteristics and, at the same time, their social and economic benefits. In Europe, the industry of plastics employs 1 million people while the annual profits exceed €350 billion (Chen and Tan, 2021). Their unique attributes, such as durability, resistance, convenience of producing and processing, being lightweight, low-cost manufacturing with efficiency gains, and their effectiveness as insulating material in constructions, all facilitate the widespread application of plastics among diverse industrial sectors (Storz and Vorlop, 2013; De Marchi et al., 2020). Plastic packaging allows food and beverages to prolong their shelf life and remain fresh, reliable and safe to consume (De Marchi et al., 2020). Plastics are produced from the combination of synthetic and semi-synthetic polymers that originate from crude petroleum. One of the main disadvantages of plastic materials is that they break down very slowly (i.e. it can take up to hundreds of years). Their mismanagement as a waste leads to plastic pollution affecting waterways (and eventually oceans) as well as air quality and soil degradation in the form of microplastics (Storz and Vorlop, 2013; De Marchi et al., 2020).

The exponential growth of human population and economic growth both drive the production of synthetic polymers that reached 288 million tonnes in 2012 (Gadhave et al., 2018; Storz and Vorlop, 2013) and exceeded 359 million tonnes in 2018 (Marichelvam et al., 2018; Mehta et al., 2020; Chen and Tan, 2021). In terms of plastic packaging, approximately 1 million units of plastic bottled water are purchased per minute (De Marchi et al., 2020). Germany has one of the largest shares in the market of plastics and is the primary producer of plastics in Europe. In 2012, the German plastic industry produced 19.5 million tonnes with profits reaching €25.1 billion (Storz and Vorlop, 2013). The ever-increasing growth in plastic use has raised considerable environmental concerns with the United Nations declaring plastic pollution an urgent planetary crisis of immense proportions (Reddy et al., 2013; Blanc et al., 2019). This is because the production of plastics is linked with high carbon intensity and up to 100 million tonnes of plastics turn into waste on an annual basis (Blanc et al., 2019; Gadhave et al., 2018; Marichelvam et al., 2018). The hazardous plastic waste deluge is nowadays affecting every region of the world and is a major global environmental problem. Supporting evidence for this claim indicate that 80-85% of marine litter found on Europe's coastlines is plastic waste, with 50% of European marine litter comprises of single-use plastics, while global ecosystems' damage from plastic pollution is estimated up to of €10 billion/year. In this respect, the impact of plastic pollution on Europe's fishing industry is reaching €300 million/year (Reddy et al., 2013; Blanc et al., 2019).

Faced with such alarming rates, industry and research have sought to find new materials in an attempt to substitute synthetic polymers with bio-based feedstocks (Reddy et al., 2013; Storz and Vorlop, 2013; Gadhave et al., 2018; Marichelvam et al., 2018; Blanc et al., 2019; Dilkes-Hoffman et al., 2019; De Marchi et al., 2020). Bioplastic is a polymer that is produced using bio-based inputs and methods (Storz and Vorlop, 2013; Dilkes-Hoffman et al., 2019). Thus, key differences between regular/conventional and bio-based plastics pertain to their raw materials and manufacturing processes: whereas conventional plastics are produced using fossil fuel, bio-based plastics derive from biomass (Alaerts et al., 2018). Specifically, natural polymers (i.e. bio-plastics) have oxygen and nitrogen in their structure. Such ingredients allow certain types of bioplastics to biodegrade (Gadhave et al., 2018). Bio-based plastics can be produced using procedures with reduced environmental impacts that, among other benefits, reduce CO_2 emissions, and consequently, air pollution (Reddy et al., 2013; Blanc et al., 2019). The market of biodegradable polymers involves materials such as plastic bags, packaging, personal care

products (shampoos), laminated paper, toys, swabs, and agri-based products including organic fertilizer (Gadhave et al., 2018). Bioplastics may reach the capacity to substitute 90% of conventional plastic products produced. Still, the comparatively higher production costs and the low producing capacity of bio-based plastics hinders their market development and penetration. Evidence indicates that the production of bio-based products holds 1% of total plastic production but its market share is expected to increase over the next years. With this in mind, the bioplastics industry could be the catalyst for change in the production and consumption of conventional plastics and become a crucial pillar for the long-term growth of sustainable, 'bioeconomy-oriented', supply chain systems (Storz and Vorlop, 2013; Alaerts et al., 2018; Gadhave et al., 2018).

The most common types of bioplastics are produced from polymers using cellulose, starch, poly-lactic acid (PLA), and poly-3-hydroxybytyrate (PHB) (Reddy et al., 2013; Blanc et al., 2019). Cellulose is a basic ingredient of plant cells and wood, and it is broadly used in the production of plastic wrappers (Storz and Vorlop, 2013; Gadhave et al., 2018). Starch is a polysaccharide which originates from wheat, potatoes, and mainly from corn. The greater amount of starch that is produced globally, is mainly used in pharmaceutical industry (Reddy et al., 2013) as well as in producing thermoplastic starch (TPS) (Storz and Vorlop, 2013; Gadhave et al., 2018). Bioplastics based on starch involve plastics such as plates, coffee cups, cutlery, plates, and packages (Gadhave et al., 2018; Marichelvam et al., 2018). Over the last few years, the production of bio-based PET packages has significantly increased and is found to allow significant reductions (approximately 20%) in greenhouse gas emissions and non-renewable energy use (Storz and Vorlop, 2013; Silva, 2021). In particular, the production of PET packages was 600.000 tonnes in 2014 and nowadays exceeds 7 million tonnes. In this respect, the market share of such packages from 35.4% reached 76.5% in 2019 (Prieto, 2016; Silva, 2021). PLA it is a transparent bioplastic which is produced using starch from crops (mainly corn, potatoes, and sugarcane) and is used in a wide array of products including computers, aluminum foil, biodegradable cups, bottles and packaging material. PLA is produced using less raw material (e.g. sugarcane) compared to other bioplastics (Theinsathid et al., 2011; Reddy et al., 2013; Gadhave et al., 2018); it is biodegradable can be recyclable (Reddy et al., 2013). In addition, CO_2 emissions of during the production of PLA are less compared to other polymers. Because of its properties, PLA is regarded as an extremely efficient bioplastic (Theinsathid et al., 2011; Reddy et al., 2013; Gadhave et al., 2018). PHB is produced from sea hyacinth and it is used in a wide array of material including packages, ropes, notepads, and automobile items (Reddy et al., 2013; Gadhave et al., 2018).

The shift from conventional plastics to bioplastics encapsulates a spectrum of environmental, social and financial implications. To achieve such a transition, it is crucial to shed light and better understand consumer attitudes and perceptions of bioplastic products. While the benefits of bioplastics are well-established in the literature (e.g. Gadhave et al., 2018; Raidani et al., 2020), they also carry certain disadvantages as they cannot enter the same recycling streams with conventional plastics due to their raw materials and ingredients in their structure. Likewise, when biodegradable plastics are not properly discarded, their decomposition may release toxics in the environment (Reddy et al., 2013). Such properties suggest that the investigation of consumers' attitudes towards bioplastics will offer fruitful insights on consumption barriers that warrant policy interventions and/or opportunities to further enhance market penetration. In view of the above, the purpose of this ongoing study is to delineate consumers' preferences, beliefs, and perceptions of bioplastics. The rest of this research note is structured as follows. Section 1 reviews prior literature, outlining consumers' attitudes towards these bio-based materials. Section 2 outlines the method and the sample. Section 3 illustrates an excerpt of the empirical

results by outlining findings drawn from the interviews. The study concludes with future research perspectives and research implications.

Literature review

Recent studies confirm that consumers are highly concerned about (micro)plastic pollution and its detrimental effects on human health and environmental quality (e.g. see Soares et al., 2021; Filho et al., 2021). Soares et al. (2021) suggest that the average consumer is nowadays aware of microplastic pollution and that plastics need many years to break down. However, people demonstrate insufficient knowledge with regards to specific negative effects of plastic use in their everyday life, since their awareness of the released microplastics is mainly restricted to single-use plastic bags and bottles and excludes sources of microplastics such as fishing nets, textiles-fibers, and personal care products (Soares et al., 2021). Still, consumers perceive the extensive use of conventional plastics as harmful, demonstrate negative reactions to them, and typically have a positive attitude toward bioplastic. In this respect, recent findings from different national contexts indicate consumers' intention to replace fossil-based plastics with bioplastics (Dilkes-Hoffman et al., 2019; Allison et al., 2021; Leal Filho et al., 2021; Mehta et al., 2021). Crucially, consumers tend to link bioplastics with primarily with attributes related to their beneficial effects including their ability to biodegrade, reuse, and recycle and much less with characteristics related to their biomass-based raw materials (Dilkes-Hoffman et al., 2019). It is the former product characteristics (i.e. safety, recycling ability, etc.) that tend to increase the perceived value of bio-based plastics in the consumers' mindset (Filho et al., 2021).

There is a substantial body of evidence suggesting that consumers' perception of bio-based products is shaped when they ask themselves "what is this product for me?" (Sijtsema et al., 2016; Allison et al., 2021). Forces that may guide individuals against bioplastics can be: i) psychological variables, such as uncertainty regarding the safety of bioplastics and failure to comprehend certain beneficial effects of bioplastics on the environment, ii) personal incentives, including a belief that bioplastic products always carry expensive, and iii) physical factors, referring to the potential inability to properly manage their disposal as wastes (Sijtsema et al., 2016; Allison et al., 2021). For instance, there is a segment of consumers who disapprove biodegradable plastic bags due to their (lack of) durability and tolerance. In addition, consumers can be hesitant and/or skeptical on the emerging technologies and innovative techniques employed for producing bio-based products. An underlying reason explaining such perception is that certain consumers tend to believe that everything that stems directly from nature is inherently good and of high quality, while products being the result of novel and/or complex manufacturing procedures are inherently 'bad' and of (comparatively) lower quality (Sijtsema et al., 2016). Moreover, previous studies also reveal that consumers have very little knowledge on the precise benefits of bioplastics, and that they are unable to define what bioplastics or bio-based plastics actually stand for (Sijtsema et al., 2016; Zwicker et al., 2021).

In this respect, previous research suggests that socio-demographic characteristics such as age, gender, education and income may influence consumer decisions to purchase bioplastics (Gill et al., 2020; Scherer et al., 2018; Yue et al., 2010). Specifically, women are found to have a more positive attitude toward bioplastics (Scherer et al., 2018; Yue et al., 2010; Notaro et al., 2022) and younger consumers find bioplastics more appealing and tend to be more willing to pay a premium price to acquire them (Yue et al., 2010; Notaro et al., 2022). Lastly, consumers of higher education have been found to demonstrate stronger environmental concerns, hence, adopt a more positive attitude towards bioplastics compared to people of basic/primary educational attainment (Yue et al., 2010; Martinho et al., 2015; Gill et al., 2020). However, these findings are far from conclusive (e.g. indicated in Klein et al., 2019; Stahl et al., 2021; Niedermeier et al.,

2021) and only serve as a conceptual starting point of possible factors affecting purchase decisions.

Material and Methods

To explore consumers' perceptions and viewpoints on bioplastics, a qualitative approach was selected, given the relatively unexplored nature of the topic in the Greek context and our aim of generating a list of consumer perspectives and concerns on bio-based plastic products.

As environmental attitudes encapsulate personal and/or subjective behavioral aspects, prone to social desirability bias, we opted for personal interviews which were all carried out at the interviewees' premises (in Greek). An interview guide was devised drawing from previous literature on green products conducted in other national contexts and by developing new questions, but heavily relying on the recent qualitative studies (see Anderson et al., 2016; Mehta et al., 2021, Roy et al., 2021) on critical stakeholder perceptions towards bioplastics. The semi-structured interview format was selected in order to facilitate a more open, yet focused, dialogue and to guide the participant through the required topics for discussion.

The interview guide begins with some general questions on plastics, plastic pollution and personal habits and moves on to more bioplastic-specific issues, allowing for some fruitful and potentially actionable insights to be gained. During all interviews, detailed field notes were taken and the transcripts were analyzed retrospectively using thematic and content analysis, with the aim of shedding light on recurring patterns of responses as well as contrasting viewpoints.

Table 1. Sample identification

Interviewee	Gender	Age	Marital status	Profession	Consumer daily purchasing habits	Recycling rate
Z.I.	female	38	Single	Researcher	Mainly from super-markets and rarely (1-2 times/ month) from organic products shops	Daily recycling of plastic bottles
M.E.	female	29	Single	Ph.D. candidate	Mainly from super-markets and rarely (1-2 times/ month) from organic products shops	Frequent recycling of plastic packaging
M.M.	female	35	Single	Sales assistant	Super-markets	Frequent recycling of plastic waste
S.S.	male	43	Single	Freelancer	Exclusively from super-markets	Frequent recycling of plastic packaging
S.A.	male	32	Single	Freelancer	Mainly from super-markets and rarely (1-2 times/ month) from organic products shops	Frequent recycling of plastic packaging
H.G.	male	37	Married (w. 1 child)	Business consultant	Exclusively from large super-markets	Daily sorting of recyclable items
E.K.	male	38	Married (w. 2 children)	Civil servant	Primarily from super-markets; occasionally from local retail stores and shops selling organic products	Daily sorting of recyclable items
S.T.	female	72	Widow (w. 1 child)	Pensioner	Super-markets	Daily sorting of recyclable items

In this regard, eight face-to-face interviews were conducted with general consumers from Greece (i.e. potential buyers of bioplastic products) as the source of primary data collection. Interviewees are aged between 29 and 72 years, recruited using a snowball and convenience sampling approach. Table 1 outlines the participants' characteristics in terms of age, gender, marital status, profession, key purchasing habits as well as recycling behavior. Interviews lasted between 30-45 minutes, depending on the level of participation of the interviewees to the study.

An outline of preliminary findings

Grounded on the content and thematic analysis conducted, certain patterns of thoughts, attitudes, and perceptions emerged from the interviews shedding light on purchase intentions toward bioplastic products as well as underlying concerns. Factors, including environmental knowledge, consumer preferences, and acceptance of bio-based products, were found to shape attitudes and the relative willingness to pay for bioplastics. A summary of preliminary findings, structured around key themes we touched upon the interviews, is outlined as follows:

1. Consumers' environmental knowledge on negative impacts of plastics and microplastic pollution: The qualitative data revealed that all participants have a certain level of awareness of the environmental quality impacts plastics carry and health risks that microplastics encapsulate. One interviewee indicated: "*I believe that microplastics are strongly associated*

with human health issues as they entail toxic chemicals that may cause cancer (…), as such, I generally avoid single-use plastics and apparel made from synthetic fibers" (Z.I., female, 38yrs). Another participant relevantly commented: "*I do know that plastics need too many years to break down and decompose (…) I believe that we should all change our daily habits and substitute traditional plastics with bioplastics to protect the planet (...) I feel sad when I think that while most people now know about the negative effects of plastics, they still prefer to buy them*" (M.E., female, 29yrs). H.G. (male, 37yrs) described plastic as a '*necessary evil*', being '*literally*' in every aspect of our daily lives and stressed that the term '*toxicity*' is associated to the term 'plastic product'. Negative connotations to the word 'petroleum-based plastics' were also indicated by E.K. (male, 48yrs), mentioning the adjectives '*harmful*', '*overproduced*' and '*wasteful*'.

2. Making a shift from plastics to plant-based plastics, bioplastics made from agro-waste and crop residues: All interviewees accepted the wider use of bioplastics produced from crops and agro-waste. Specifically, a participant proposed that: "*I would be willing to pay 10% more to buy such bioplastic products in order to reduce the amount of waste globally*" (S.S., male, 43yrs). Nevertheless, some respondents expressed concerns on the possible impacts the growth of the plant-based bioplastics sector could have on food availability and security, suggesting that it could lead to conflicting land uses. E.K. (male, 48yrs) relevantly commented that "*I am only worried whether in the long term bioplastics from crops may undermine the availability of certain agricultural products (…) we can't have contradicting targets (…) with food security competing 'green' plastics*".
3. Skepticism and reservations towards bio-based plastic food product packaging/wraps made from slaughterhouse byproducts/waste: Contradictory viewpoints were identified regarding the use of bioplastic packaging made from slaughterhouse waste and animal blood. Some participants appeared to be at least skeptical or reluctant to buy food products with such bioplastic packaging and expressed a level of discomfort. Likewise, two respondents expressed ethical concerns regarding this type of bioplastic in terms of a possible rise in killing animals for bioplastic which stressed as unacceptable. An interviewee indicated: "*I would be cautious on the use of such bioplastics because I believe that are produced using 'raw materials' of low quality*" (S.A., male, 32yrs). In contrast, another participant pointed out that the development and use of such types of bioplastics could be particularly beneficial because (this way) our dependence on important non-renewable natural resources is reduced (Z.I., female, 38yrs), while H.G. (male, 37yrs) *relevantly stressed that "I prefer having them turned into plastic wraps rather than piling up at the illegal waste dumps or the already saturated landfills we have*".
4. Hesitance towards non-food bioplastics from slaughterhouse waste: Most interviewees were also rather hesitant while few others eager to buy non-food bioplastic products that originate from slaughterhouse wastes. Specifically, a participant claimed that: "*I wouldn't prefer such products because I believe that they would consist of low-quality raw materials*" (S.S., male, 43yrs), while Z.I. (female, 38yrs) argued that "*I would support the use of non-food bioplastics that originate from animal blood (…) I believe it is essential to engage large companies like Lego or Ikea in using such materials when manufacturing their products*". In contrast, S.T. (female, 73yrs) maintained that such bioplastic products would most likely be of questionable quality and their long-term durability could not possibly match those of conventional plastics, making them (in her opinion) inferior goods.

5. Positive attitude toward PLA bioplastics: Interestingly, most interviewees expressed a positive attitude toward PLA-based bioplastics which was also reflected on their willingness to pay a higher price for such biopolymer products compared to plastics made from fossil-fuel feedstock. In particular, M.M. (female, 35yrs) argued that: "*Although the price of PLA bioplastics can be higher than the others, I would be willing a premium price because of its high-quality raw materials and its bio-based production procedures*". However, it was only two respondents (E.K., male, 48yrs; H.G., male, 37yrs) that expressed reservations on PLA biopolymers denoting that they may not be a well-aimed solution to the plastic pollution problem because they carry comparable levels of toxicity to that of petroleum-based ones. G.H. further pointed out that while these products could reduce the economy's reliance to fossil fuels, they may have little impact to environmental quality loss, and further added that it is the greenwashing messages of large producers that confuses the average consumer with misleading or ambiguous messages around the actual environmental benefits of PLA biopolymers.
6. Willingness to pay (WTP) for bioplastics: All participants indicated a WTP more for bioplastics of their choice. Interestingly, a participant claimed that: "*I believe that the replacement of plastics with bioplastics could be beneficial for everyone (…) I am willing to pay 20%-30% more for such bioplastics because these products eventually contribute to the maintenance of our health*" (Z.I., female, 38yrs). Similarly, M.M. (female, 35yrs) stated that: "*Bioplastic is a sustainable solution since they are produced from natural materials and many of them can be biodegradable (…) I would be willing to pay 5-10% more to purchase such products and consequently to contribute to the protection of the environment*". S.T. (female, 73yrs) and E.K. (male, 48yrs) pointed out their intention to purchase such products for a small premium (2% and 5%, respectively) if only the products matched the overall quality of the conventional ones.
7. Preferences for biodegradable bioplastics: All interviewees were in favor of the use of biodegradable bioplastics compared to (non-biodegradable) bio-based plastic products which can be recycled, stressing the domestic - particularly low - existing recycling rates and the relative '*indifference of the average Greek consumer*' (H.G., male, 37yrs) to properly sort recyclables into the appropriate waste streams. Such statements were further amplified when we stressed to interviewees that these new materials would require different waste management treatments and pertain to separate recycling streams from those of fossil-based plastic wastes: "(…) *we can't even sort those (conventional) wastes which 'supposedly' should go in the blue (i.e. recycling) bin! (…) adding another one (i.e. bin) next to it will make things even worse…*" (S.T., female, 73yrs). Z.I. (female, 38yrs) relevantly stated: "(…) *personally, I would prefer the wide use of biodegradable products (…) in a case in which I couldn't use biodegradable products, a good solution for me would be the use of conventional which can be recycled (i.e. through the blue bins)*". Interestingly, it was only E.K. (male, 48yrs) that touch upon the notion of a plastic-free world and the need to move away from plastic products and packaging in all its forms and reduce their overall use, as - in his opinion - either biodegradable or non-biodegradable, bioplastics are nothing more than a '*modest response*' to "*a world drowning in plastic*".

Final remarks

In this research note we attempt to provide some preliminary insights from Greek consumers' viewpoints on the emerging market for bioplastic products. Since contrasting respondent profiles can be a prerequisite in order to capture various prevailing attitudes and perceptions we aim to expand this study using a more diverse pool of consumers. Likewise, as this is an ongoing study, we seek to include other key stakeholder perspectives on the bioplastic industry's underlying challenges and opportunities by drawing from major retailers and importers of such products to the domestic market.

As prior literature confirms that consumers' familiarity with bioplastic products is lacking in key respects (e.g. Dilkes-Hoffman et al., 2019; Mehta et al., 2021), findings such as ours may inform decision-makers and practitioners (i.e. bioplastic producers) on socioeconomic aspects that may facilitate better engagement with key actors. Such stakeholder engagement can give room to more effective marketing and pricing strategies, product labelling and better communication of end-of-life attributes for safe disposal. Crucially, outcomes of this engagement can feed into relevant public awareness-raising/outreach campaigns to increase consumers' acceptability of bioplastics, mobilize the power of the public in support of bio-based products and, ultimately, curb the pressing plastic pollution threats.

References

Alaerts, L., Augustinus, M., & Van Acker, K. (2018). Impact of bio-based plastics on current recycling of plastics. Sustainability, 10(5), 1487.

Allison, A. L., Lorencatto, F., Michie, S., & Miodownik, M. (2021). Barriers and enablers to buying biodegradable and compostable plastic packaging. Sustainability, 13(3), 1463.

Anderson, A.G., Grose, J., Pahl, S., Thompson, R. C., & Wyles, K. J. (2016). Microplastics in personal care products: Exploring perceptions of environmentalists, beauticians and students. Marine Pollution Bulletin, 113(1-2), 454-460.

Blanc, S., Massaglia, S., Brun, F., Peano, C., Mosso, A., & Giuggioli, N.R. (2019). Use of bio-based plastics in the fruit supply chain: An integrated approach to assess environmental, economic, and social sustainability. Sustainability, 11(9), 2475.

Chen, Z., & Tan, A. (2021). Exploring the circular supply chain to reduce plastic waste in Singapore. Logforum, 17(2), 271-286

De Marchi, E., Pigliafreddo, S., Banterle, A., Parolini, M., & Cavaliere, A. (2020). Plastic packaging goes sustainable: An analysis of consumer preferences for plastic water bottles. Environmental Science and Policy, 114, 305-311.

Dilkes-Hoffman, L., Ashworth, P., Laycock, B., Pratt, S., & Lant, P. (2019). Public attitudes towards bioplastics–knowledge, perception and end-of-life management. Resources, Conservation and Recycling, 151, 104479.

Gadhave, R.V., Das, A., Mahanwar, P. A., & Gadekar, P.T. (2018). Starch based bio-plastics: The future of sustainable packaging. Open Journal of Polymer Chemistry, 8(2), 21-33.

Gill, M.B., Jensen, K.L., Upendram, S., Labbé, N., English, B.C., Lambert, D.M., ... & Menard, R.J. (2020). Tennessee consumer willingness to pay for disposable dinnerware molded from wheat straw. Journal of Food Distribution Research, 51(2), 19-39.

Klein, F., Emberger-Klein, A., Menrad, K., Möhring, W., & Blesin, J.M. (2019). Influencing factors for the purchase intention of consumers choosing bioplastic products in Germany. Sustainable Production and Consumption, 19, 33–43.

Leal Filho, W., Salvia, A.L., Bonoli, A., Saari, U.A., Voronova, V., Klõga, M., ... & Barbir, J. (2021). An assessment of attitudes towards plastics and bioplastics in Europe. Science of the Total Environment, 755, 142732.

Marichelvam, M. K., Jawaid, M., & Asim, M. (2019). Corn and rice starch-based bio-plastics as alternative packaging materials. Fibers, 7(4), 32.

Martinho, G., Pires A., Portela G., & Fonseca. M. (2015). Factors affecting consumers' choices concerning sustainable packaging during product purchase and recycling. Resources, Conservation and Recycling, 103, 58-68.

Mehta, N., Cunningham, E., Roy, D., Cathcart, A., Dempster, M., Berry, E., & Smyth, B.M. (2021). Exploring perceptions of environmental professionals, plastic processors, students and consumers of bio-based plastics: Informing the development of the sector. Sustainable Production and Consumption, 26, 574-587.

Niedermeier, A., Emberger-Klein, A., & Menrad, K. (2021). Which factors distinguish the different consumer segments of green fast-moving consumer goods in Germany?. Business Strategy and the Environment, 36, 360.

Notaro S., Lovera E., & Paletto A. (2021). Consumers' preferences for bioplastic products: A discrete choice experiment with a focus on purchase drivers. Journal of Cleaner Production, 330, 129870.

Prieto, A. (2016). To be, or not to be biodegradable… that is the question for the biobased plastics. Microbial Biotechnology, 9(5), 652-657.

Reddy, R.L., Reddy, V.S., & Gupta, G.A. (2013). Study of bio-plastics as green and sustainable alternative to plastics. International Journal of Emerging Technology and Advanced Engineering, 3(5), 76-81.

Roy, D., Berry, E., & Dempster, M. (2021). "If it is not made easy for me, I will just not bother". Barriers and Facilitators to Recycling Plastics. PsyArXiv, doi: 10.31234/osf.io/bkpqw.

Scherer, C., Emberger-Klein, A., & Menrad, K. (2018). Segmentation of interested and less interested consumers in sports equipment made of bio-based plastic. Sustainable Production and Consumption, 14, 53-65.

Sijtsema, S.J., Onwezen, M.C., Reinders, M.J., Dagevos, H., Partanen, A., & Meeusen, M. (2016). Consumer perception of bio-based products - An exploratory study in 5 European countries. NJAS - Wageningen Journal of Life Sciences, 77, 61-69.

Silva, A.L.P. (2021). Future-proofing plastic waste management for a circular Bio-economy. Current Opinion in Environmental Science & Health, 22, 100263.

Soares, J., Miguel, I., Venâncio, C., Lopes, I., & Oliveira, M. (2021). Public views on plastic pollution: Knowledge, perceived impacts, and pro-environmental behaviours. Journal of Hazardous Materials, 412, 125227.

Stahl, F.F., Emberger-Klein, A., & Menrad, K. (2021). Consumer preferences in Germany for bio-based apparel with low and moderate prices, and the influence of specific factors in distinguishing between these groups. Frontiers in Sustainability, 2, 624913.

Storz, H., & Vorlop, K. D. (2013). Bio-based plastics: status, challenges and trends. Landbauforschung, 63(4), 321-332.

Theinsathid, P., Chandrachai, A., Suwannathep, S., & Keeratipibul, S. (2011). Lead users and early adopters of bioplastics: A market-led approach to innovative food packaging films. Journal of Biobased Materials and Bioenergy, 5(1), 17-29.

Yue, C., Hall, C.R., Behe, B.K., Campbell, B.L., Dennis, J.H., & Lopez, R.G. (2010). Are consumers willing to pay more for biodegradable containers than for plastic ones? Evidence from hypothetical conjoint analysis and nonhypothetical experimental auctions. Agricultural & Applied Economics, 42, 757-772.

Zwicker, M.V., Brick, C., Gruter, G.J.M., & van Harreveld, F. (2021). (Not) doing the right things for the wrong reasons: An investigation of consumer attitudes, perceptions, and willingness to pay for bio-based plastics. Sustainability, 13(12), 6819.

We acknowledge support of this work by the project “Center of Sustainable and Circular Bioeconomy [Aegean_BIOECONOMY]” (MIS 5045851) which is implemented under the Action “Reinforcement of the Research and Innovation Infrastructure”, funded by the Operational Programme "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014-2020) and co-financed by Greece and the European Union (European Regional Development Fund).

Consumer preferences for bio-based products: Preliminary findings from an ongoing investigation

Skouloudis Antonios[1], **Panagiotopoulou Altani**[2],
Chrysovalantis Malesios[3] & **Lekkas Demetris-Francis**[1]
[1] Dep. of Environment, University of the Aegean,
[2] Dep. of Marketing & Communication, Athens University of Economics & Business
[3] Dep. of Agricultural Economics & Development, Agricultural University of Athens
skouloudis@aegean.gr, *apanagiotopoulou@aueb.gr*, *malesios@aua.gr*, *dlekkas@aegean.gr*

Abstract
The purpose of this study is to examine consumer preferences for bio-based products. In this regard, a survey was conducted using self-reported scales assessing the effects of individuals' characteristics such as innovativeness, trust in science and technology, environmental concern, and previous experience with bio-products on consumer preferences, i.e. willingness to pay more (WTPm) for: a) a bio-nylon jacket, b) a pack of bio-based breadsticks, and c) a bioplastic bottled water. Findings results indicate that certain individuals' attributes may influence WTPm for the three bio-based products included in our study. In this respect, the results encapsulate managerial/practical and policy implications towards the development of appropriate advertising messages and awareness-raising campaigns and indicate the need to further explore consumers' preferences for bio-based products in the Greek context.

Keywords: Consumer preferences, willingness to pay, bio-based products; Greece.

Introduction - Background

Grounded on its growth and recognition, bioeconomy is characterized as a circular catalyst for radical socioeconomic and environmental sustainability transitions (Hao et al., 201; Konuk, 2019). Consumers are affected by such structural changes and tend to demonstrate their environmental consciousness through their purchasing behavior towards bio-products and a willingness to pay a premium price (WTPm) for such products (Hao et al., 2019). Global environmental issues such as climate change and biodiversity decline stimulate this shift in consumer preferences and encourage a growing customer base for bio-based products and services (Berger, 2017). Studies on consumer preferences for green products span from food products and beverages to electronics and furniture (Shen, 2012; Min et al., 2017). Specifically, previous studies reveal that consumers demonstrate the intention to pay a premium price for bio-batteries (Shen, 2012; Choi et al., 2018), environmentally-friendly product packaging (Hao et al., 2019), processed foods produced using bio-based procedures (Aryal et al., 2009), eco-friendly textiles and apparel (Lee, 2011), eco-labeled products ranging from consumer electronics to recycled paper (e.g. Shen, 2012; Min et al., 2017).

Numerous scholars have focused on fast-moving consumer goods and found that a range of parameters affect consumers' WTP for products, including those that encapsulate bio-based characteristics. Specifically, there is a body of evidence suggesting that consumers' WTP for environmentally-friendly products is shaped by two main groups of variables: i) product-related attributes and ii) individuals'-related attributes (e.g. Aryal et al., 2009; Shen, 2012; Rezai et al., 2013; Biswas and Roi, 2016). The most critical product-related factors are product price, quality, safety, product certifications, the type of product (i.e. disposable or non-disposable), product availability as well as the country of origin (Aryal et al, 2009; Muhammad et al., 2015). Individuals' related parameters tend to refer to personal values and characteristics (i.e. environmental consciousness and concern, perceptions and attitude towards green products as well as awareness of the 'green' concepts and the detrimental effects of consuming products of high environmental footprint). In this respect, previous studies have also indicated that socio-demographic characteristics including gender, age, education level, profession may explain consumer behavior and WTP for green products (Aryal et al., 2009; Rezai et al., 2013; Muhammad et al., 2015; Berger, 2017; Konuk, 2019; Lee, 2011). In particular, women are found to be more eager to pay a premium price for environmentally-friendly products compared to men (Choi et al., 2018; Park, 2018). Available income affects consumers' tendency to purchase 'greener' products. Previous conceptual and empirical studies agree that high-income people spend a greater amount of money to consume ethically- and responsibly-produced products relative to their lower-income counterparts, since such products tend to be regarded as luxury goods (Rezai et al., 2013; Park, 2018). Education level can play a moderating role in shaping consumers' perceptions of bio-based products, as people of higher education tend to have a more positive attitude and are more willing to pay a premium price for green products than individuals of basic educational attainment (Park, 2018). Moreover, scholars provide supporting evidence that consumer preferences diversify among the different age groups (Liu et al., 2017; Kucher et al., 2019). Young people are found to be more eager to purchase and consume new products than middle-aged and senior ones. This partially implies that older people may have limited access on information related to new products (such as the bio-based ones), an asymmetry that increases their resistance to change and drive them towards more conventional solutions (Royne et al., 2011; Kucher et al., 2019). Regarding personal characteristics, a recent wave of studies suggests that consumer altruism and innovativeness, green consumer values, purchase intentions, previous product experience, interest in and attitude toward bio-based products, can be significant parameters that shape consumer preferences and may drive individuals to pay a premium price for bio-based consumer goods (Klein et al., 2019; Stahl et al., 2021).

The theory of planned behavior provides conceptual underpinning in describing the effects of specific variables such as demographic characteristics on consumer behavior. Drawing from this theory, Rezai et al. (2013) propose that internal forces such as individuals' socio-demographic profile influences their attitude towards green(er) products and subsequently, their WTP a premium price for these products (Rezai et al. 2013). In general, consumers decide whether they consume a product relying on three factors: a) their knowledge about product attributes (such as product labelling, their relative interest and previous experience with the specific products driving purchase intentions), b) their attitudes in relation to the product (such as consumer altruism and innovativeness and consumers' environmental concern), affecting c) their WTP for the product (Aryal et al. 2014; Klein et al., 2019; Kucher et al., 2019; Stahl et

al., 2021). Since bio-based products are often regarded as credence goods and their acceptability depends on their production methods and quality (i.e. quality that is often associated with health benefits, effectiveness, and/or the appearance of bio-based products), consumers' knowledge regarding which products are produced using bio-based processes may guide their decisions. That is because, knowledge about the beneficial effects of bio-based products on environmental quality and health increases consumers' positive viewpoints towards such products and stimulates their WTP a premium price (Aryal et al., 2009; Muhammad et al., 2015; Kucher et al., 2019). Crucially, when such knowledge is combined with trust in institutions certifying green products, consumers perceive products of this market segment as safer, more sustainable and/or healthier compared to conventional ones (Krystallis and Chryssohoidis, 2005; Kucher et al., 2019).

Product attributes that typically foster one's knowledge and positive attitude towards bio-based products are the quality of provided information, product labelling and certifications (Aryal et al., 2009; Muhammad et al., 2015). In cases in which certifications regarding the production standards of a product are absent, consumers are less likely to pay a premium price to buy it (Michaud and Lierena, 2010). A large body of literature indicates that apart from knowledge, environmental concern may also motivate consumers to support producers who embrace corporate environmental responsibility (CER) practices and produce green(er) products with eco-friendly attributes (Royne et al., 2011; Rezai et al., 2013; Harms and Linton, 2015; Biswas and Roi, 2016; de Medeiros et al., 2016; Reinders et al., 2017; Hao et al., 2019; Konuk, 2019; Lee, 2011;). Guided by the need to decrease the perceived risks that are associated with an upcoming purchase, consumers with high environmental concern pay considerable attention to products that are eco-certified (Harms and Linton, 2015).

As a general rule, consumers assess whether the price of a product is fair and acceptable based on a reference product of the same category. In this respect, people evaluate the price of a bio-based product after comparing it with conventional ones and in cases in which their knowledge is insufficient, they rely on advertising messages, their personal value system, perceptions and behavioral attributes to decide whether they will buy such a product and the amount they are willing to pay (Park, 2018; Bhatt et al., 2020). Several studies have sought to explain the critical importance of pricing in consumer decision-making for purchasing a product (Michaud and Lierena, 2010; Liu et al., 2017; Choi et al., 2018; Bhatt et al., 2020) The basic economic model suggests that people make choices between alternative options that maximize their anticipated utility and minimize the costs. Therefore, when people are faced with two alternative options, they prefer the one that offers the highest anticipated utility per cost unit (Park, 2018). Although the bio-based products are more expensive than respective conventional ones, certain consumers demonstrate willingness to pay a premium price, especially, when they believe that their materials contribute to products of particularly high added-value (Berger, 2017). Since most of bio-based products have the above-mentioned characteristic, their perceived value in consumers' decision-making processes increases and price sensitivity decreases. Consequently, consumers exhibit WTP more for these products partially because of the added-value of product attributes (Muhammad et al., 2015; de Medeiros et al., 2016).

Material and methods

The preliminary findings of this study rely on a sample of 132 people aged between 16-60yrs (53% was female and 47% was male) that participated in our survey which took place during July-September 2021 using a structured questionnaire. Participants were instructed to answer a battery of self-reported statements using a 5-point agreement scale that measures aspects of their personal beliefs, perceptions and attitudes along with their WTPm for:

a) Breadsticks fortified with phenolic extracts from olive mill wastewater,

b) A jacket made from bio-nylon, i.e. renewably-sourced, plant-based, textiles, and

c) Bottled water in bioplastic bottle, made from polyhydroxyalkanoate (PHA) biopolymer which is produced by a variety of microorganisms through bacterial fermentation.

Dependent variable:

Willingness to pay a premium price (WTPm) for the above bio-products is measured using the following two items adopted and revised from Laroche et al. (2001) and Schniederjans and Starkey (2014): "*I am willing to pay a higher price for this 'bio-based product than for a respective, regular, one*", and, ''*Even if the 'regular product' is priced lower, I will still buy the ''bio-based' product*".

Independent Variables

Altruism (ALTR), denoting prosocial behavioral intentions, is measured using an adapted scale drawn from Price et al. (1995; 2018).

Consumer innovativeness (INNOV), denoting the consumer's attraction to novelty of new products, is assessed using a reformulated scale developed by Tellis et al. (2009) and also applied in the study of Scherer et al. (2017) assessing consumer preferences for bio-based plastic products.

Trust in science (TRUSTSCI), denoting consumers' perceptions of science and technology advancements, is measured through the standardized items previously identified by Miller et al. (1997) and Miller and Kimmel (2001).

Product Labeling (PRODLAB) is operationalized using a common factor of four standardized items measuring consumer choices based on information provision, reflecting agreement with the following statements: 'An important criterion when I choose a product is: i) the information on the label regarding the product's country of origin, ii) the information on the label regarding the certification of the product's production methods, iii) the information on the label regarding the raw materials used to produce it, and iv) the information on the label regarding the origin of key ingredients/main raw materials.

Lack of environmental concern (ENVCONC), reflecting negative attitudes toward environmentally responsible behaviors, i.e. the likelihood to engage in pro-environmental behaviors (Paul et al., 2016) is measured (using reverse scored items) through an adapted version of the scale identified by Ellen et al. (1991) and Schwepker and Cornwell (1991).

Attitude toward bio-products (ATTITOBIO), *purchase intention for bio-based products (PURCHINT)* and *previous experience with bio-products (PRODEXP)* are operationalized using the scales drawn from Klein et al. (2019).

Sociodemographic descriptors in terms of *gender*, *age*, *education* and *income* were employed as categorical variables.

Model specification and statistical analysis

In order to model the response variable of WTPm factor based on the explanatory variables described above, we utilize a statistical regression modeling approach (Draper and Smith, 1998). In this respect, linear regression estimation and inference was performed assuming the following model equation (1):

$$\begin{aligned}WTPm = {} & b_0 + b_1*[INTINBIO=Not\ at\ all] + b_2*[INTINBIO=A\ little] + b_3*[INTINBIO=Fairly\ enough] + b_4*[INTINBIO=A\ lot] + b_5*PRODEXP + b_6*PRODLAB + b_7*ALTR + b_8*INNOV + \\ & b_9*ENVCONC + b_{10}*TRUSTSCI + b_{11}*ATTITOBIO + b_{12}*PURCHINT + b_{13}*[GENDER=male] + b_{14}*[AGE=<19yrs] + b_{15}*[AGE=20\text{-}29yrs] + b_{16}*[AGE=40\text{-}59yrs] + b_{17}*[INCOME=<1000€] \\ & + b_{18}*[INCOME=1001\text{-}2000€] + b_{19}*[INCOME=2001\text{-}3000€] + b_{20}*[EDU=primary] + b_{21}*[EDU=secondary] + b_{22}*[EDU=graduate] + b_{23}*[EDU=postgraduate] + \varepsilon\end{aligned} \quad (1)$$

where b_0 is the intercept, and $\beta_j \ (j=1,..,23)$ are the regression coefficients of the continuous and categorical explanatory variables. The error term is used for measuring the unexplained variance in the dependent variables due to covariates, and is distributed as a Gaussian random variable with zero mean and constant variance σ^2. For estimating the regression model parameters in the three different fitted models (substudies), the Ordinary Least Squares (OLS) method was employed, whereas selection of the best fitted model in each case that includes only statistically significant explanatory variables, was performed by utilizing the backward selection technique. The latter is chosen in order to account for potential correlation among all the covariates under consideration (i.e. the full model) and to finally derive

the best-fitted regression model to the collected data. Goodness-of-fit for all models was assessed by the coefficient of determination, R^2. Data were fitted to the three linear regression models via the use of SPSS 21.0 statistical software (IBM Corporation, 2012). Lastly, to ensure the validity and reliability of the regression modelling, the percentage of variance explained and Cronbach's α values were extracted (Bollen, 1989) for each of the latent factors utilized as dependent and independent variables in the regression models.

Findings

Table 1 reports the percentage of variance and Cronbach's α values for the three dependent latent variables (WTPm) and the explanatory latent constructs.

Factor	% of variance explained	Cronbach's α
WTPm (Breadsticks)	92.13	0.915
WTPm (Jacket)	88.25	0.866
WTPm (Bottled Water)	94.86	0.945
ALTR	62.03	0.843
INNOV	64.24	0.769
TRUSTSCI	56.78	0.693
PRODLAB	72.98	0.869
ENVCONC	51.16	0.687
PURCHINT	86.43	0.841
ATTITOBIO	49.59	0.844

Table 1. Validity and reliability measures for the dependent factor variables

The dependent variables and covariates which are factors are suitable for further analysis through regression modelling since the variables are explaining the largest proportion of the variance in the initial selected items and, in general, values are over 50%, while the items are reliable as revealed by the generally high Cronbach alpha values.

Table 2 presents the statistically significant explanatory variables as were selected by the application of the backward selection technique. Different explanatory variables have been found to be statistically significant for each of the three regression models (bio-based products), with only the categorical variable of age being an explanatory variable in all three WTP models.

In terms of model fit, the R^2 values range between 0.396 (bioplastic bottled water) and 0.521 (bio-nylon jacket), indicating a moderate fit for the fitted models. This indicates that there is still considerable variation in the dependent variables that is not explained by the current covariates.

Table 3 includes the parameter estimates for the three WTP regression models, along with the respective statistical significance (p-value) and the corresponding 95% confidence intervals for each of the parameters. Our results obtained are outlined in brief for each one of the fitted models after covariate selection as follows.

Substudy 1 findings: Breadsticks

Variables of [PRODLAB] and [ATTITOBIO] positively affect the WTP for breadsticks, at the 10% and 1% significance level, respectively. This indicates that the higher the value in these two explanatory variables, the higher the level of WTP. In contrast, [ENVCONC] (i.e. the lack of environmental concern) is found to affect WTP in a negative way (beta = -0.407; p-value<0.001). Those who answered "A little" in the [INTINBIO] are more possible to exhibit higher WTP in comparison to all other categories at the 5% significance level (beta = 1.137; p-value=0.025<0.05) – a findings that certainly warrants further investigation. Age and income have both an effect on WTP for bio-breadsticks. Younger people are less willing to pay compared to other age groups (beta = -2.414; p-value=0.014<0.05). Lastly, those of middle

income are less willing to pay when compared to small and high income groups (beta = -0.527; p-value=0.019<0.05).

Substudy 2 findings: Bio-nylon jacket

Regression results indicate that [TRUSTSCI] and [PURCHINT] affect in a positive way the consumers' WTP for a bio-nylon jacket (beta = 0.192 and beta = 0.276, respectively). There is also a negative association between [ENVCONC] and WTP at the 5% significance level (beta = -0.185; p-value=0.017<0.05). Those who answered "Not at all" in the [INTINBIO] variable are less likely to exhibit a higher WTP compared to all the other categories at the 5% significance level (beta = -1.736; p-value=0.028<0.05). Those with no previous experience with bio-based products (i.e. those who answered 'No' in the [PRODEXP] questionnaire item) are less willing to pay for a bio-nylon jacket compared to those with relevant product experience (beta = -0.551; p-value=0.001<0.01). In terms of demographics, it is only age that seems to have an effect on WTP, with younger respondents demonstrating lower levels of WTPm in comparison to older ones (beta = -2.565; p-value=0.006<0.01).

Substudy 3 findings: Bioplastic bottled water

Results suggest a positive and statistically significant association between WTPm and [INNOV] (beta = 0.186; p-value<0.05), [ATTITOBIO] (beta = 0.346; p-value<0.01) and [PURCHINT] (beta = 0.245; p-value<0.05). A negative association between WTPm and [ALTR] is also identified, i.e. the higher the level of altruism describing the consumer, the lower the level of WTPm for a bioplastic bottled water (beta = -0.162; p-value=0.041<0.05) – a finding that merits further investigation in future research. Age is a significant predictor, as in the previous two substudies, with people of young age being less willing to pay a premium price for bioplastic bottled water at the 1% level of significance (beta = -3.482; p-value=0.001<0.01).

Concluding remarks – next steps

This ongoing study, whose preliminary findings are presented here, explores the impact of specific product and consumer-related parameters on the WTPm of Greek consumers for a diverse set of bio-based products. It encapsulates implications in terms of bio-based products' future communication, advertising and promotional/marketing strategies towards both the general public and the pertinent critical supply chain stakeholders. Despite the fact that the results reported here do not support all the expected associations, we believe that the statistically significant findings make a useful contribution to a better understanding of the extent to which consumer and product-specific characteristics may influence WTPm for products of this emerging market segment. Findings suggest that factors such as consumer altruism, previous experience with bio-products, purchase intentions towards bio-products, consumers' environmental concern and certain demographic characteristics may explain WTPm for bio-based products. In particular, we found that personal characteristics such as trust in science, and purchase intentions towards bio-based products may be conceptualized as antecedents of WTP for bio-nylon jacket. Environmental concern drives individuals towards purchasing both a bio-nylon jacket and bio-breadsticks. In a similar vein, previous product experience with bio-based products may negatively affect consumer purchasing decisions, since people who have never previously acquired bio-based products appear to be less willing to pay a premium price for a bio-nylon jacket. Findings also indicate that product labelling, the general attitude towards bio-based products, and consumers generally demonstrating little interest in bio-products may pay a premium price for bio-breadsticks; a finding that needs further investigation in terms of consumer behavior perhaps by employing choice experiments. In the case of bio-plastic bottled water, consumer innovativeness, attitude and relevant purchase intentions may explain WTPm whereas altruism may reduce consumers' WTP for the product; a finding that also require further a deeper investigation using mixed methods approaches. Regarding demographic characteristics, all three substudies indicate that age has a negative impact on consumer preferences for bio-based products: younger respondents demonstrated a lower WTP for the three products. In contrast, the study's results

did not confirm the expected critical effect of available income in shaping WTPm for the bio-based products. Our study points out that there is plenty of room for further investigation into the factors that shape certain purchasing decisions under the scope of the bioeconomy transitions in Greece. As this is an ongoing study, our primary aim is to refine the indicative conceptual framework presented here and draw from a larger sample of Greek consumers. Re-examining scales/variables such as altruism, previous experience with bio-products and WTPm for bio-products may allow as to further delineate causal relationships of such variables (along with psychological factors explaining them). In this sense, we may better understand aspects describing the essence of consumer reactions towards bio-based products and motivate organizations to employ appropriate, product-specific, advertising campaigns to attract consumers' attention by effectively communicating the multidimensional benefits of bio-based products.

References

Aryal, K. P., Chaudhary, P., Pandit, S., & Sharma, G. (2009). Consumers' willingness to pay for organic products: a case from Kathmandu valley. Journal of Agriculture and Environment, 10, 15-26.

Berger, J. (2019). Signaling can increase consumers' willingness to pay for green products. Theoretical model and experimental evidence. Journal of consumer behaviour, 18(3), 233-246.

Bhatt, S., Ye, H., Deutsch, J., Ayaz, H., & Suri, R. (2020). Consumers' willingness to pay for upcycled foods. Food Quality and Preference, 86, 104035.

Biswas, A., & Roy, M. (2016). A study of consumers' willingness to pay for green products. Journal of Advanced Management Science, 4(3).

Choi, Y., Chen, K. J., & Marsh, T. L. (2020). Consumer preference for bio-based batteries. Journal of Consumer Behaviour, 19(4), 382-396.

de Medeiros, J. F., Ribeiro, J. L. D., & Cortimiglia, M. N. (2016). Influence of perceived value on purchasing decisions of green products in Brazil. Journal of Cleaner Production, 110, 158-169.

Ellen, P.S., Wiener, J.L., Cobb-Walgren, C. (1991). The role of perceived consumer effectiveness in motivating environmentally conscious behaviors. J. Pub. Policy Mark. 10 (2), 102–117.

Hao, Y., Liu, H., Chen, H., Sha, Y., Ji, H., & Fan, J. (2019). What affect consumers' willingness to pay for green packaging? Evidence from China. Resources, Conservation and Recycling, 141, 21-29.

Harms, R., & Linton, J. D. (2016). Willingness to pay for eco-certified refurbished products: The effects of environmental attitudes and knowledge. Journal of industrial ecology, 20(4), 893-904.

Klein, F., Emberger-Klein, A., Menrad, K., Möhring, W., & Blesin, J. M. (2019). Influencing factors for the purchase intention of consumers choosing bioplastic products in Germany. Sustainable Production and Consumption, 19, 33-43.

Konuk, F. A. (2019). Consumers' willingness to buy and willingness to pay for fair trade food: The influence of consciousness for fair consumption, environmental concern, trust and innovativeness. Food research international, 120, 141-147.

Krystallis, A., & Chryssohoidis, G. (2005). Consumers' willingness to pay for organic food: Factors that affect it and variation per organic product type. British food journal.

Kucher, A., Hełdak, M., Kucher, L., & Raszka, B. (2019). Factors forming the consumers' willingness to pay a price premium for ecological goods in Ukraine. International Journal of Environmental Research and Public Health, 16(5), 859.

Laroche, M., Bergeron, J., & Barbaro-Forleo, G. (2001). Targeting consumers who are willing to pay more for environmentally friendly products. J. Consum. Mark. 18 (6), 503–520.

Lee, S. (2011). Consumers' value, environmental consciousness, and willingness to pay more toward green-apparel products. Journal of Global Fashion Marketing, 2(3), 161-169.

Liu, Y., Yang, D., & Xu, H. (2017). Factors influencing consumer willingness to pay for low-carbon products: A simulation study in China. Business Strategy and the Environment, 26(7), 972-984.

Michaud, C., & Llerena, D. (2011). Green consumer behaviour: an experimental analysis of willingness to pay for remanufactured products. Business Strategy and the Environment, 20(6), 408-420.

Miller, J. D., & Kimmel, L. (2001). Biomedical communications: Purposes, audiences, and strategies. New York: Academic Press.

Miller, J. D., Pardo, R., & Niwa, F. (1997). Public perceptions of science and technology:A comparative study of the European Union, the United States, Japan, and Canada. Chicago: Chicago Academy of Sciences.

Min, S. H., Lim, S. Y., & Yoo, S. H. (2017). Consumers' willingness to pay a premium for eco-labeled LED TVs in Korea: A contingent valuation study. Sustainability, 9(5), 814.

Muhammad, S., Fathelrahman, E., & Ullah, R. U. T. (2015). Factors Affecting Consumers' Willingness to Pay for Certified Organic Food Products in United Arab Emirates. Journal of Food Distribution Research, 46(1).

Park, K.C. (2018). Understanding ethical consumers: Willingness-to-pay by moral cause. Journal of Consumer Marketing.

Paul, J., Modi, A., Patel, J., 2016. Predicting green product consumption using theory of planned behavior and reasoned action. J. Retail. Consum. Serv. 29, 123–134.

Price, Linda L., Feick, Lawrence F., Guskey, Audrey, 1995. Everyday market helping behavior. J. Publ. Policy Mark. 14 (2), 255–266.

Price, L. L., Feick, L. F., and Guskey, A. (2018). Everyday market helping behavior. J. Public Policy Market. 14, 255–266. doi: 10.1177/074391569501400207

Reinders, M. J., Onwezen, M. C., & Meeusen, M. J. (2017). Can bio-based attributes upgrade a brand? How partial and full use of bio-based materials affects the purchase intention of brands. Journal of Cleaner Production, 162, 1169-1179.

Rezai, G., Kit Teng, P., Mohamed, Z., & Shamsudin, M. N. (2013). Consumer willingness to pay for green food in Malaysia. Journal of International Food & Agribusiness Marketing, 25(sup1), 1-18.

Royne, M. B., Levy, M., & Martinez, J. (2011). The public health implications of consumers' environmental concern and their willingness to pay for an eco-friendly product. Journal of Consumer Affairs, 45(2), 329-343.

Scherer, C., Emberger-Klein, A., & Menrad, K. (2017). Biogenic product alternatives for children: consumer preferences for a set of sand toys made of bio-based plastic. Sustainable Production and Consumption. 10, 1–14.

Schniederjans, D. G., & Starkey, C. M. (2014). Intention and willingness to pay for green freight transportation: An empirical examination. Transportation Research Part D: Transport and Environment, 31, 116-125.

Schwepker Jr, C.H., & Cornwell, T.B. (1991). An examination of ecologically concerned consumers and their intention to purchase ecologically packaged products. Journal of Public Policy and Marketing. 10 (2), 77-101.

Shen, J. (2012). Understanding the determinants of consumers' willingness to pay for eco-labeled products: An empirical analysis of the China Environmental Label. Journal of Service Science and Management. 5(1), 87-94.

Stahl, F.F., Emberger-Klein, A., & Menrad, K. (2021). Consumer preferences in Germany for bio-based apparel with low and moderate prices, and the influence of specific factors in distinguishing between these groups. Frontiers in Sustainability, 2, 624913.

Tellis, G.J., Yin, E., & Bell, S., (2009). Global consumer innovativeness - Cross-country differences and demographic commonalities. Journal of International Marketing, 17(2), 1-22.

We acknowledge support of this work by the project "Center of Sustainable and Circular Bioeconomy [Aegean_BIOECONOMY]" (MIS 5045851) which is implemented under the Action "Reinforcement of the Research and Innovation Infrastructure", funded by the Operational Programme "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014-2020) and co-financed by Greece and the European Union (European Regional Development Fund).

European Union
European Regional Development Fund

HELLENIC REPUBLIC
MINISTRY OF ECONOMY & DEVELOPMENT
SPECIAL SECRETARY FOR ERDF & CF

EPAnEK 2014-2020
OPERATIONAL PROGRAMME
COMPETITIVENESS ENTREPRENEURSHIP INNOVATION

ΕΣΠΑ 2014-2020
Partnership Agreement 2014 - 2020

Co-financed by Greece and the European Union

Table 2. Test of statistically significant effects for the models' covariates

	Breadsticks					**Jacket**					**Bottled Water**				
Source	Type III Sum of Squares	df	Mean Square	F	p-value	Type III Sum of Squares	df	Mean Square	F	p-value	Type III Sum of Squares	df	Mean Square	F	p-value
Intercept	1.332	1	1.332	2.291	0.133	2.903	1	2.903	5.549	0.020	5.043	1	5.043	7.904	0.006
INTINBIO	4.616	4	1.154	1.985	0.101	3.619	4	0.905	1.729	0.148					
PRODEXP						6.273	1	6.273	11.990	0.001					
PRODLAB	1.843	1	1.843	3.169	0.078										
ALTR											2.719	1	2.719	4.261	0.041
INNOV											3.531	1	3.531	5.535	0.020
ENVCONC	14.894	1	14.894	25.616	<0.001	3.042	1	3.042	5.815	0.017					
TRUSTSCI						3.195	1	3.195	6.106	0.015					
ATTITOWBIO	8.590	1	8.590	14.775	<0.001						7.015	1	7.015	10.994	0.001
AGE	5.415	3	1.805	3.105	0.029	4.917	3	1.639	3.132	0.028	10.728	3	3.426	5.369	0.002
INCOME	7.985	3	2.662	4.578	0.005										
PURCHINT						4.640	1	4.640	8.868	0.004					
Error	68.607	118	0.581			62.783	120	0.523			79.119	124	0.638		
Total	131,000	132				131,000	132				131,000	132			
Corrected Total	131,000	131				131,000	131				131,000	131			

a. Breadsticks model: R squared = 0.476 (Adjusted R Squared = 0.419)
b. Jacket model: R squared = 0.521 (Adjusted R Squared = 0.477)
c. Bottled Water model: R squared = 0.396 (Adjusted R Squared = 0.362)

Table 3. Parameter estimates along with significances and corresponding confidence intervals for the finally selected covariates in all three models

	Breadsticks						Jacket						Bottled water					
					95% Confidence Interval						95% Confidence Interval						95% Confidence Interval	
Parameter	B	Std. Error	t	p-value	Lower Bound	Upper Bound	B	Std. Error	t	p-value	Lower Bound	Upper Bound	B	Std. Error	t	p-value	Lower Bound	Upper Bound
Intercept	0.078	0.612	0.127	0.899	-1.135	1.290	0.890	0.543	1.638	0.104	-0.186	1.966	0.313	0.575	0.545	0.587	-0.825	1.451
PRODEXP (Ref. Category = Yes)																		
[PRODEXP=No]							-0.551	0.159	-3.463	0.001	-0.866	-0.236						
INTINBIO (Ref. Category = Very much)																		
[INTINBIO=Not at all]	-0.253	0.900	-0.281	0.079	-2.035	1.529	-1.736	0.778	-2.231	0.028	-3.277	-0.196						
[INTINBIO=A little]	1.137	0.501	2.272	0.025	0.146	2.129	0.330	0.509	0.648	0.518	-0.678	1.339						
[INTINBIO=Fairly enough]	0.032	0.251	0.127	0.899	-0.465	0.529	-0.157	0.246	-0.639	0.524	-0.644	0.330						
[INTINBIO=Pretty much]	0.257	0.201	1.284	0.202	-0.140	0.665	-0.174	0.182	-0.956	0.341	-0.533	0.186						
AGE (Ref. Category = 60+yrs)																		
[AGE=<19yrs]	-2.414	0.971	-2.487	0.014	-4.336	-0.492	-2.565	0.925	-2.773	0.006	-4.397	-0.733	-3.482	0.996	-3.497	0.001	-5.453	-1.511
[AGE=20-39yrs]	-0.041	0.553	-0.074	0.941	-1.136	1.054	-0.511	0.523	-0.978	0.330	-1.546	0.524	-0.245	0.585	-0.419	0.676	-1.402	0.912
[AGE=40-59yrs]	0.066	0.563	0.117	0.907	-1.050	1.181	-0.685	0.526	-1.300	0.196	-1.727	0.358	-0.363	0.583	-0.623	0.534	-1.518	0.791
INCOME (Ref. Category = >3001€)																		
[INCOME=<1000€]	-0.307	0.230	-1.333	0.185	-0.763	0.149												
[INCOME=1001-2000€]	-0.527	0.221	-2.385	0.019	-0.964	-0.089												
[INCOME=2001-3000€]	0.137	0.233	0.586	0.559	-0.325	0.598												
ALTR													-0.162	0.079	-2.064	0.041	-0.318	-0.007
INNOV													0.186	0.079	2.353	0.020	0.029	0.342
PRODLAB	0.143	0.080	1.780	0.078	-0.302	0.016												
ENVCONC	-0.407	0.080	-5.061	<0.001	-0.566	-0.248	-0.185	0.077	-2.411	0.017	-0.338	-0.033						
ATTITOWBIO	0.370	0.096	3.844	<0.001	0.179	0.561							0.346	0.104	3.316	0.001	0.140	0.553
TRUSTSCI							0.192	0.078	2.471	0.015	0.038	0.346						
PURCHINT							0.276	0.093	2.978	0.004	0.093	0.460	0.245	0.097	2.521	0.013	0.53	0.437

Workplace human rights assessment in sustainability reports: An overview of the United Kingdom market

Stefanos Fotiadis & Konstantinos Evangelinos
Centre for Environmental Policy & Strategic Environmental Management, Department of Environment, University of the Aegean, Mytilene
sfotiadis@env.aegean.gr, kevag@aegean.gr

Abstract
Organizations are responsible for their impacts on human rights directly through their own actions and operations and indirectly through their interactions and relationships with others, including governments, local communities and suppliers, and their investments. The aim of this study is to assess the level of accountability of organizations based in the United Kingdom (UK) on issues of human rights at work (HRW), expressed by nine fundamental disclosures of the Global Reporting Initiative (GRI) manual. Our sample consists of one hundred and seventy-three organizations, from thirty-four different business sectors whose Corporate Social Responsibility (CSR) reports for 2019 were accessed from the GRI database. The overall findings indicate that organizations in the UK exhibit a very low level of compliance with regards to workplace human rights issues. Most sample reports demonstrate poor statements on the assessed topic. In contrast to the majority, four reports performed moderately and one somewhat satisfactorily at incorporating these types of GRI principles into their annual disclosures.

Keywords: CSR, GRI Standards, rights and principles at work, accountability.

JEL Codes: G34; M14; O16; Q01; Q56.

Honeybee Pollination Services: Challenges and Opportunities for Beekeepers and Farmers in Greece

Simeon Marnasidis[1], Garyfallos Arabatzis[1], Fani Hatjina[2], Chrisovalantis Malesios[3] and Efstathia Verikouki[4]

[1] *Department of Forestry and Management of the Environment and Natural Resources, Democritus University of Thrace, 193 Pantazidou St., 68200 Orestiada, Greece*

[2] *Department of Apiculture, Institute of Animal Science—Hellinikos Georgikos Organismos DIMITRA, 63200 Nea Moudania, Greece*

[3] *Department of Agricultural Economics and Rural Development, Agricultural University of Athens, 75 Iera Odos St., 11855Athens, Greece*

[4] *Faculty of Agriculture, Vocational School (EPAL) of Edessa, Melinas Merkouri 28, 58200 Edessa, Greece*

marnasidis@pella.gr, garamp@fmenr.duth.gr, fhatjina@instmelissocomias.gr, malesios@aua.gr, verikouki@sch.gr

Abstract

Pollination services provide substantial benefits to human populations and, more specifically, to agriculture. The aim of the current paper was to explore the possibility of providing organized honeybee pollination services in Greece, a country where such services are hardly developed, as is also the case in many other European countries. The vast majority of the beekeepers (87.8%) surveyed were of the opinion that the use of agrochemicals is the dominant problem in rural areas. Another important finding of the research is that 23.0% of the farmers who responded believe that insecticides are safe to moderately hazardous for bees, 59.2% of them hold the same view on fungicides and 46.7% on herbicides. A serious problem pinpointed by 63.4% of farmers is the fact that hives are very few and, therefore, crop pollination cannot be effectively carried out. However, only 2.4% of farmers hire pollination hives for their crops by paying rental fees. When asked if they would agree to participate in a subsidized agri-environmental program for pollination, 84.8% of beekeepers and 74.7% of farmers gave positive answers, a finding indicating that there are good prospects for the development of honeybee pollination services markets in Greece. The authors suggest that farmers should be specially informed and trained so that they may be able to avoid posing risks to bees when they apply agrochemicals. Organized hive placement in agricultural and forest areas should be re-examined within the framework of national agricultural policy.

Key words: Ecosystem; pollination services; apiculture; honeybees; rural development

JEL Codes: O13; Q18; Q57; Q58.

1. Introduction

Pollination is considered an outstanding ecosystem service provided by both wild and managed insect pollinators. Several studies show that wild pollinators in the EU have declined in abundance and diversity (European Court of Auditors, 2020). Insect decline could pose a global risk to key insect-mediated ecosystem functions and services such as pollination services (van der Sluijs, 2020). Several causes threaten both wild and honeybee pollinators: land use changes and management, pesticides, pests, diseases and bee husbandry, climate change, invasive alien species, and pollutants, to name but a few (Vanbergen, 2018). In the EU it is far less common for beekeepers to be paid for pollination services (Breeze et al., 2014; European Commission DG, Agriculture and Rural Development, 2013) and this is in contrast to other parts of the world, where the cost of pollination is consistent with other farm inputs such as seeds, fertilizers, and pesticides (European Parliament, 2019). The same is true for the United Kingdom, too; a recent study has revealed that fewer than 10% of beekeepers, mostly professionals, have actively provided crop pollination services and rarely have they received any kind of remuneration for the provision of this service (Breeze et al., 2017). On the other hand, in the US, pollination services are a source of income for many professional beekeepers. Pollination services are also an increasing trend in Germany where charging has been commonplace for the past 50 years (European Commission DG, Agriculture and Rural Development, 2013). The aim of the present paper is to investigate the possibility of providing organized honeybee pollination services in Greece, a country where such services are not well developed, as is the case in many other European countries. The systematic use of pollinating honeybees, coupled with improvements that can be implemented in their management methods (Hatjina, 1996, 1999, 2006; Hatjina et al., 1998, 2019) are expected to significantly help bridge the gap caused by factors such as the increase in cultivated land, and the emerging reduction in natural pollinators, which, as already mentioned, is likely to be due to local and global environmental degradation (Aizen et al., 2008; Hatjina et al., 2019). The effective organization of pollination services is expected to generate multiple benefits to farmers and beekeepers alike and at the same time sensitize the public to issues such as the protection of pollinators and the environment. This survey is also anticipated to contribute, together with other investigations (Breeze et al., 2017, 2019), to the knowledge base pertaining to the cooperation of farmers and beekeepers in the process of producing agricultural and beekeeping products.

2. Materials and methods

The research target population is the totality of the beekeepers and farmers of the Pella Regional Unit and the sampling method selected is the simple random sampling on the grounds of its simplicity and because it requires the least possible knowledge of the population under investigation in comparison to any other sampling method (Damianou, 1999; Kalamatianou, 1998; Matis, 2001).

As sampling framework for the beekeepers' part of the survey, we used the list of active beekeepers registered with the Administration of Rural Economy & Veterinary (702 agricultural holdings). The size of the sample was determined in accordance with the principles of simple random sampling (Kalamatianou, 1998; Matis, 2001). All in all, 221 printed questionnaires were administered, of which 132 valid ones were completed and returned. The rather low response rate is mainly due to the fact that a large number of beekeepers were hesitant about completing the questionnaires despite our given assurances of total anonymity, some others refused to answer all the questions, our urges and encouragement notwithstanding, and, lastly, some others gave ambiguous or unclear answers. Beekeepers were asked: (a) to note down the locations where they transport their hives in a one-year period; (b) to say if they provide crop pollination services and what the rental fee is; (c) to assess the seriousness of problems they are faced with in their beekeeping activities; (d) to evaluate the level of collaboration with other stakeholders; (e) to evaluate the farmers' awareness of the value of honeybees as pollinators, (f) to evaluate the stockbreeders' awareness of the value of honeybees as pollinators; (g) to answer if they have ever helped other professionals (farmers or stockbreeders) develop beekeeping skills; (h) to evaluate the possible causes of honeybee winter losses; (i) to write how many hives they

own; (j) to say if they would be eager to participate in an information network for beehive placement; (k) to say if they would wish to participate in a fast track training program on beekeeping; (l) to say if they would participate in an agri-environmental program designed to promote pollination services and state the desired amount of subsidy they would wish to receive. There were also another six questions concerning the financial results of beekeeping, the main profession of the beekeepers and their education level.

The farmer population under investigation comprised 18,600 farmers who had submitted a single payment application for the year 2019, according to the Greek Payment Authority of Common Agricultural Policy (C.A.P.) Aid Schemes statistics. The maximum allowable sample size was 260 people. However, as there was no list of farmers available and we wished to include as many crops as possible, 500 questionnaires were sent out throughout the research area, of which 410 were returned, comprising the final size of the sample. The farmers' questionnaire requested participants to: (a) name the crops they grow; (b) evaluate the harmfulness of pesticides to bees; (c) name the contents of the labels of the pesticides they use; (d) evaluate problems arising from beekeeping activities in their area; (e) evaluate the necessity of honeybees to their crops; (f) evaluate the level of collaboration with beekeepers, (h) say if they would participate in an information network for beehive placement; (g) answer if they would participate in a fast track training program for beekeepers; (h) say if they are also engaged in beekeeping activities and, if yes, how many hives they own, (i) write the size of their cultivated area (in hectares); (j) say if they have ever received practical training from beekeepers, (k) answer if they would participate in an agri-environmental program designed to develop pollination services and state the desired amount of subsidy they would wish to receive. There were also two additional questions concerning their main profession and education level.

Statistical analysis was performed with the use of SPSS, Version 21.0. The questionnaires we collected were analyzed by means of descriptive statistics methods, the non-parametric Mann-Whitney U test and the Friedman statistical test. The non-parametric Mann-Whitney U test was employed to test the equality of means in two independent samples (Roussos & Tsaousis, 2002). Friedman's statistical test was applied to the multi-thematic questionnaires, in order to compare k dependent samples of a given variable X whose data is serial (ordinal scale). This test examines whether k dependent samples (repeated measurements of the same variable) differ in their mean ranks and constitutes the maximum (serial) non-parametric equivalent of the analysis of variance (ANOVA) for dependent samples. The test is based on the following assumptions: (a) random samples, (b) data independence between subjects, and (c) same form distributions (Freund & Wilson, 2003).

3. Results and discussion

3.1 Hive placement areas

Pine forests (Table 2) constitute the primary area that beekeepers prefer to transport their colonies to. In addition, they travel to the following, in order of preference: grasslands with deciduous shrubs, forest lands, and mixed areas with pastures and crops.

Table 2. Ranking hive placement areas with the application of Friedman test

Type of area	Mean Ranks (Friedman test)	Frequency	
		Often-always	Rarely-never
Pine forests	16.54	94.60%	5.40%
Natural grasslands	15.14	87.10%	12.90%
Forest areas	13.84	78.90%	21.10%
Mixed areas (crops-grasslands)	11.74	65.20%	34.80%
Mixed fruit tree areas	10.77	60.60%	39.40%
Sweet cherry orchards	10.41	53.10%	46.90%
Phrygana and shrubs	10.42	57.30%	42.70%
Leguminous crops	10.70	55.30%	44.70%
Cotton fields	9.13	42.40%	57.60%
Almond orchards	9.09	44.00%	56.00%
Mixed areas (crops-phrygana)	9.15	40.10%	59.90%
Aromatic plants-herbs	9.13	38.60%	61.40%
Sunflower fields	9.11	37.90%	62.10%
Areas with annual plants	8.75	38.50%	61.50%
Rapeseed fields	8.66	37.10%	62.90%
Peach orchards	8.23	36.30%	63.70%
Apricot orchards	7.25	24.10%	75.90%
Citrus fruit orchards	6.09	18.90%	81.10%
Pome fruits	5.85	13.60%	86.40%

From the responses of beekeepers regarding the placement of hives in crops, it can be observed that 86.4%, 63.7%, 46.9% and 75.8% of them rarely or never at all carry their hives to areas with pome fruits, peach trees, cherry orchards, and apricot orchards respectively, which means that the actual number of hives transported to crops is considerably smaller than that kept by beekeepers. Especially in cross-pollinated crops with fruit setting problems such as sweet cherry orchards, the lack of bees and, more generally, the lack of pollinators can lead to inadequate fertilization (Isaacs et al., 2017; Underwood et al., 2017) and seriously affect yields (Reilly et al., 2020). Data relating to the actual number of hives shipped to crops is of crucial importance as it helps assess the adequacy and economic value of the pollination services provided by honeybees.

3.2 Views of beekeepers

According to 87.8% of the beekeepers surveyed, the dominant problem, which is considered to be of moderate to great seriousness in rural areas, is the application of agrochemicals to crops (Table 3). This is clearly a matter that requires urgent attention, as has also been demonstrated in another recent study, in which it turned out that 55.8% of the beekeepers in Thassos, Greece's northernmost island, had the same view (Tampakis et al., 2019). In Greece, farmers in certain regions, for instance, almond producers in Larissa, central Greece, complain about pesticide applications by their colleagues, protest by locking water pumps thus preventing their colleagues from irrigating their crops, and ask growers to refrain from spraying with pesticides during the day (*Eleftheria* Newspaper, 2019).

Table 3. Ranking the problems faced by beekeepers with the use of Friedman test

Problem	Mean Ranks (Friedman test)	Frequency	
		Moderate-very serious problem	No problem-minor problem
Pesticides	10.08	87.8%	12.2%
Lack of Nectar	7.22	63.4%	36.6%
Roadside placement of hives	6.90	63.4%	36.6%
Lack of space	6.83	62.7%	37.3%
Extreme weather conditions	6.62	58.8%	41.2%
Transmission of diseases	6.59	57.3%	42.7%
Stockbreeders' behavior	6.48	52.3%	47.7%
Difficult access	6.29	54.2%	45.8%
Farmers' behavior	6.17	51.1%	48.9%
Lack of Pollen	5.69	44.6%	55.4%
Beekeepers' behavior	4.63	30.5%	69.5%
Complaints from residents	4.52	29.8%	70.2%

The unavoidable placement of hives near or on rural/forest roads as well as the lack of nectar are generally viewed as problems by a large proportion of beekeepers (63.4); the lack of space is also regarded as a serious problem by 62.7% of the participants. It should be noted here that, according to Greek legislation (Law 4856/1930 and Law 6238/1934), hives are placed almost freely (the only restrictions that are currently in place regulate the minimum distance from roads) on public land (meadows and forests) and inside fields, following written consent of owners. However, there is no provision whatsoever regarding the creation or designation of hive locations in forest areas, a fact that must be taken into account in forest management policy-making (Marnasidis et al., 2021). Placing hives in the vicinity of or on forest roads makes debris removal and the cleaning of wooded areas difficult, thus resulting in forest fire hazards (Dasarxeio.com, 2015; Ypaithros Newspaper, 2018). As far as the lack of nectar is concerned, this issue does not seem to constitute a generalized problem situation for Greece, since annual production has increased between 2010 and 2018 from 16,237 tn to 22,288 tn (FAOSTAT, 2021). The average yield calculated on the basis of the results of the present survey stands at 18.2 kg / hive and is slightly higher in comparison with the 16.5 kg / hive average yield calculated for an average holding of 270 hives for the year 2010 (Papanagiotou, 2010).

Table 4. Ranking the causes leading to winter colony losses by means of Friedman statistical test

Problem	Mean Ranks (Friedman test)	Frequency	
		Serious-very serious problem	No problem-Moderate problem
Varroa mite	7.46	40.9%	59.1%
Nosema infection	7.45	37.8%	62.2%
Climate change	7.13	31.8%	68.2%
Nutrition problems	6.29	25.8%	74.2%
Old Queen	6.03	19.7%	80.3%
High humidity	6.0	22.7%	77.3%
Over-wintering place	5.47	22.8%	77.2%
No honey stocks	5.36	19.7%	80.3%
Frost and freeze	5.0	12.1%	87.9%
Winter inspections	4.95	18.9%	81.1%
CCD	4.86	16.9%	83.1%

Bee loss during the winter, according to beekeepers, is mainly due to the infestation of the colonies from the varroa mite and Nosema apis diseases, problems that are considered to be very serious by 40.9% and 37.8% of beekeepers, respectively (Table 4). Overall, 31.8% of beekeepers consider climate change to be an equally serious problem. According to studies, climate change can cause stress on bees and changes in the vegetation of large regions (Le Conte & Navajas, 2008; Zittis et al., 2019). Last but not least, 33.3% of beekeepers would be willing to participate periodically and 58.3% on a permanent basis in a fast-track beekeeping training project, a fact that indicates that beekeepers are interested in constantly improving their knowledge and skills.

3.3 Views of farmers

Almost two-thirds of the farmer participants (63.4%) expressed concerns about the low numbers of hives leading to crop pollination failures (Table 5). Other problems reported by the farmers surveyed include the unknown identity of the hive owner (47.9%) and the absence of information on the positions where hives are placed (46.8%).

Table 5. Ranking the problems arising from hive placement in crops, with the application of Friedman test

Problem	Mean Ranks (Friedman test)	Frequency	
		Moderate-very serious problem	No problem minor problem
Insufficient number of HB col.	4.29	63.4%	36.6
Unknown owner	3.83	47.9%	52.1%
Unknown position	3.69	46.85%	53.2%
Restrictions on agrochemicals	3.66	39.3%	60.7%
Complaints of disturbance	2.79	19.6%	80.4%
Large numbers of beehives	2.74	18.3%	81.7%

Twenty-three percent of farmers regard insecticides as safe to moderately hazardous for bees, 59.2% believe that fungicides are safe to moderately hazardous and 46.7% have the opinion that herbicides are safe to moderately hazardous (Table 6). From their responses, it is apparent that farmers are not, in their entirety, thoroughly aware of the effects of agrochemicals on bees. Different groups of agrochemicals

seriously impact the health of social insects in a variety of ways and, therefore, affect their sensitivity to diseases through different paths (Feldhaar & Otti, 2020). For example, some fungicides can even double the acute toxicity of neonicotinoid insecticides in bees (Tsvetkov et al., 2017). Exposure of bees to glyphosate, the broad-spectrum herbicide, can disrupt the beneficial intestinal microflora of bees, possibly affecting their health and their effectiveness as pollinators (Motta et al., 2018).

Table 6. Ranking the harmfulness of agrochemicals to bees with the application of Friedman test

Pesticide toxicity to bees	Mean Ranks (Friedman test)	Frequency	
		Dangerous-too dangerous	Safe-moderately dangerous
Insecticides	4.12	77.0%	23.0%
Herbicides	3.52	53.3%	46.7%
Fungicides	3.11	40.9%	59.2%
Plant growth regulators	2.22	18.4%	81.5%
Foliar fertilizers	2.03	16.2%	83.9%

A Greek study showed that 73% of bee samples with death incidents were positive in at least one plant protection product (Kasiotis et al., 2014). Agrochemicals act synergistically with other stressors, such as parasites and insufficient nutrition, contributing to the mortality of bees (Siviter et al., 2021). On the whole, 37.3% of the respondent farmers state that they have not noticed the indications on the labels of agrochemicals. This finding causes reasonable concern as it is also corroborated by an official Greek survey, in which it was highlighted that almost 20% of the respondents replied that they did not read the labels or that they read them but failed to understand them; in addition, 16% of respondents maintained they never or not always followed a pesticide's indications for the protection of bees and the environment (Hellenic Ministry of Rural Development and Food, 2018).

3.4 Beekeeper-farmer relations

All in all, 61.1% of beekeepers have good to excellent communication with tree-growers and 59.5% of them are on good to excellent terms with arable crop producers. Furthermore, 60.3% of beekeepers have helped with their knowledge and expertise farmers who are interested in beekeeping. However, 51.1% of beekeepers regard farmers' behavior as a moderate to serious problem due to hive placement issues (Table 3) and 66.5% of beekeepers believe that farmers are not at all to very little aware of the value of bees in pollination.

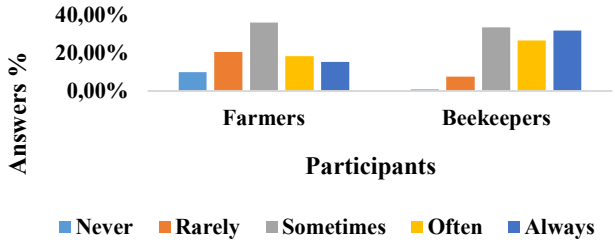
3.4 Beekeeper-stockbreeder relations

Over half of the beekeepers (52.3%) consider the behavior of stockbreeders to be a moderate to very important problem, due to hive placement issues (Table 3). As few as 40.4% of them are on good to excellent terms with stockbreeders and 78.7% of them believe that breeders are not at all or barely informed about the value of bees in maintaining biodiversity.

3.6 Pollination services

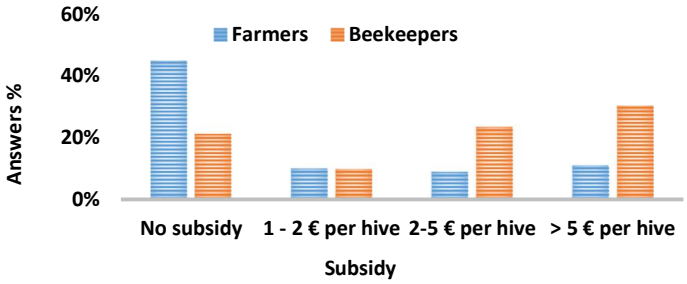
Whilst 20.2% of farmers believe that bees are quite necessary in their area, 64.9% of respondents stated that bees are extremely necessary.

Figure 1. Participation in a network providing information on hive placement



Nevertheless, only a small minority (2.4%) hire pollination hives for their crops by paying rental fees and only 33.7% would be very eager to participate in a network providing information on hive placement (figure 1).

Figure 2. Participation in a subsidized agri-environmental program designed to promote pollination services



If we now turn to beekeepers, 32.6% of respondents (43 people) carry their hives to tree crops for pollination and only 6.0% (8 beekeepers) are paid for this with fees ranging from 5 to 25 euro per hive. The majority of beekeepers (69.7%) commented that they would certainly participate in an information network on hive placement. Both beekeepers (84.8%) and farmers (74.7%) would participate in an agri-environmental program for pollination (Mann-Whitney Test: Z= -1.904; p-value=0.057>0.05); 44.9% of farmers would agree to do it without a subsidy (figure 2), whereas only 21.2% of beekeepers would do the same without any kind of aid (Mann-Whitney Test: Z=-4.887; p-value<0.001).

4. Conclusions

The pollination of plants carried out by honeybees is an ecosystem service that farmers regard as necessary for their crops and which most of them receive free of charge from beekeepers. An information network on the placement of hives in rural areas could significantly enhance the development of pollination services. Beyond doubt, what would further promote them is the implementation of a subsidized crop pollination program. Farmers should be take information on both the benefits of protecting the bees and the dangers of pesticides. They should also carefully read the labels of agrochemicals before any application in to crops at blooming. Stockbreeders should also be informed about the value of honeybees in preserving biodiversity so that they may cooperate with beekeepers when placing hives in the countryside.

The numerous problems that arise from the placement of hives in arable and forest areas show the low degree of organization of nomadic beekeeping in Greece. The correct and well-organized placement of hives in forestlands is a very important consideration that needs to be re-examined within the framework of national agricultural policy.

Data relating to the actual number of hives transported to crops is essential and must be collected in order to assess the adequacy and economic value of the pollination services provided by honeybees.

Ethics approvals

The competent ethics committee has approved the questionnaires of the paper. Name of the ethics committee: Research Ethics Committee (R.E.C.). Institution: Democritus University of Thrace. Approval number: ΔΠΘ/ΕΗΔΕ/27073/164/ 3-12-2019.

References

Aizen, M. A., Garibaldi, L. A., Cunningham, S. A., & Klein, A. M. (2008). Long-Term Global Trends in Crop Yield and Production Reveal No Current Pollination Shortage but Increasing Pollinator Dependency. Current Biology, 18(20), 1572–1575. https://doi.org/10.1016/j.cub.2008.08.066.

Breeze, T. D., Boreux, V., Cole, L., Dicks, L., Klein, A.-M., Pufal, G., Balzan, M. V., Bevk, D., Bortolotti, L., Petanidou, T., Mand, M., Pinto, M. A., Scheper, J., Stanisavljević, L., Stavrinides, M. C., Tscheulin, T., Varnava, A., & Kleijn, D. (2019). Linking farmer and beekeeper preferences with ecological knowledge to improve crop pollination. People and Nature, 1(4), 562–572. https://doi.org/10.1002/pan3.10055.

Breeze, T., Dean, R., & Potts, S. G. (2017). The costs of beekeeping for pollination services in the UK – an explorative study. Journal of Apicultural Research, 56(3), 310–317. https://doi.org/10.1080/00218839.2017.1304518.

Breeze, T. D., Vaissière, B. E., Bommarco, R., Petanidou, T., Seraphides, N., Kozák, L., Scheper, J., Biesmeijer, J. C., Kleijn, D., Gyldenkærne, S., Moretti, M., Holzschuh, A., Steffan-Dewenter, I., Stout, J. C., Pärtel, M., Zobel, M., & Potts, S. G. (2014). Agricultural Policies Exacerbate Honeybee Pollination Service Supply-Demand Mismatches Across Europe. PLOS ONE, 9(1), e82996. https://doi.org/10.1371/journal.pone.0082996.

Damianou, C. (1999). Sampling Methodology: Techniques and applications. (Third print).

Dasarxeio.com. (2015). The problem for the Forest authorities is the uncontrolled placement of hives in forests. https://dasarxeio.com/2015/09/25/24026/ (accessed on 06 August 2021).

Eleftheria newspaper. (2019). Don't kill the Bees! https://www.eleftheria.gr/ (accessed on 06 August 2021).

European Commission DG, Agriculture and Rural Development. (2013). Evaluation of Measures for the Apiculture Sector: Final Report. July 2013. https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/key_policies/documents/ext-eval-apiculture-leaflet_2013_en.pdf (accessed on 06 August 2021).

European Court of Auditors. (2020). Protection of wild pollinators in the EU: Commission initiatives have not borne fruit. Special report No 15, 2020. Publications Office of the European Union. https://data.europa.eu/doi/10.2865/962753 (accessed on 06 August 2021).

European Parliament. (2019). European Parliament resolution of 18 December 2019 on the EU Pollinators Initiative. https://www.europarl.europa.eu/doceo/document/TA-9-2019-0104_EN.html (accessed on 06 August 2021).

FAOSTAT. (2021). Livestock Primary Statistics. http://www.fao.org/faostat/en/#data/QL (accessed on 06 August 2021).

Feldhaar, H., & Otti, O. (2020). Pollutants and Their Interaction with Diseases of Social Hymenoptera. Insects, 11(3), 153. https://doi.org/10.3390/insects11030153.

Freund, R., & Wilson, W. (2003). Statistical Methods (2nd ed.). Academic Press. https://www.elsevier.com/books/statistical-methods/freund/978-0-08-049822-5.

Hatjina, F. (1996). The use of 'temporary confinement' and 'pollen transfer devices' to increase pollination potential of honey bees [Ph. D Thesis]. U.W.C.C.

Hatjina, F. (1999). Hive-entrance pollen transfer devices to increase the cross-pollination potential of honey bees. II. Examination of three materials and pollen viability.

Hatjina, F., Free, J., & Paxton, R. (1998). Hive-entrance pollen transfer devices to increase the cross-pollination potential of honey bees. I. Examination of six materials. Journal of Apicultural Research, 37, 231–237. https://doi.org/10.1080/00218839.1998.11100977.

Hatjina, F., Gajda, A., & Dar, S. A. (2019). Phylogenetics of Bees. Current Drivers of Taxonomic Biodiversity Loss in Asian and European Bees (pp. 127-153). (R. A. Ilyasov & H. W. Kwon, Eds.). CRC Press.

Hatjina, F., Haristos, L., Paxton, R., Karipidou, V., Kritikopoulou, K., Mamouzi, A., & Tsirakoglou, V. (2006). Almond pollination and the use of hive entrance pollen transfer devices. Proceedings of the Second European Conference of Apidology, 92.

Hellenic Ministry of Rural Development and Food. (2018). Results of data collection on the survey for rational use of pesticides. http://www.minagric.gr/images/stories/docs/agrotis/Georgika_Farmaka/StatisticsSustUseResults 2018.pdf (accessed on 06 August 2021).

IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.

Isaacs, R., Williams, N., Ellis, J., Pitts-Singer, T. L., Bommarco, R., & Vaughan, M. (2017). Integrated Crop Pollination: Combining strategies to ensure stable and sustainable yields of pollination-dependent crops. Basic and Applied Ecology, 22, 44–60. https://doi.org/10.1016/j.baae.2017.07.003.

Kalamatianou, A. G. (1998). Social Statistics, One-Dimensional Analysis' Methods.«. Sbilias.

Kasiotis, K. M., Anagnostopoulos, C., Anastasiadou, P., & Machera, K. (2014). Pesticide residues in honeybees, honey and bee pollen by LC–MS/MS screening: Reported death incidents in honeybees. Science of The Total Environment, 485–486, 633–642. https://doi.org/10.1016/j.scitotenv.2014.03.042.

Le Conte, Y., & Navajas, M. (2008). Changements climatiques: Impact sur les populations d'abeilles et leurs maladies. 27(2), 499–510. https://doi.org/10.20506/rst.27.2.1819.

Marnasidis, S., Kantartzis, A., Malesios, C., Hatjina, F., Arabatzis, G., & Verikouki, E. (2021). Mapping Priority Areas for Apiculture Development with the Use of Geographical Information Systems. Agriculture, 11(2), 182. https://doi.org/10.3390/agriculture11020182.

Matis, K. (2001). Forest sampling. Assets Exploitation and Management Society. Xanthi: Democritus University of Thrace.

Motta, E. V. S., Raymann, K., & Moran, N. A. (2018). Glyphosate perturbs the gut microbiota of honey bees. Proceedings of the National Academy of Sciences, 115(41), 10305. https://doi.org/10.1073/pnas.1803880115

Papanagiotou, E. (2010). Economic analysis of beekeeping in Greece [Study]. National Network of Greek Beekeeping.

Reilly, J. R., Artz, D. R., …, Winfree, R. (2020). Crop production in the USA is frequently limited by a lack of pollinators. Proceedings of the Royal Society B: Biological Sciences, 287(1931), 20200922. https://doi.org/10.1098/rspb.2020.0922.

Roussos, P., & Tsaousis, I. (2002). Statistics applied to the social sciences. Ellinika Grammata.

Siviter, H., Bailes, E. J., Martin, C. D., Oliver, T. R., Koricheva, J., Leadbeater, E., & Brown, M. J. F. (2021). Agrochemicals interact synergistically to increase bee mortality. Nature, 596(7872), 389–392. https://doi.org/10.1038/s41586-021-03787-7.

Tampakis, S., Karanikola, P., Tsoupras, S., & Tampaki, Z. (2019). Beekeeping on the island of Thassos: The views of beekeepers. Forestry, Environmental and Natural Resources Management, 11, 387–402.

Tsvetkov, N., Samson-Robert, O., Sood, K., Patel, H. S., Malena, D. A., Gajiwala, P. H., Maciukiewicz, P., Fournier, V., & Zayed, A. (2017). Chronic exposure to neonicotinoids reduces honey bee health near corn crops. Science, 356(6345), 1395. https://doi.org/10.1126/science.aam7470.

Underwood, E., Darwin, G., & Gerritsen, E. (2017). Pollinator initiatives in EU Member States: Success factors and gaps. Report for European Commission under Contract for Provision of Technical Support Related to Target, 2.

https://ec.europa.eu/environment/nature/conservation/species/pollinators/documents/ieep_2017_pollinator_initiatives_in_eu_member_states.pdf (accessed on 06 August 2021).

van der Sluijs, J. P. (2020). Insect decline, an emerging global environmental risk. Current Opinion in Environmental Sustainability, 46, 39–42. https://doi.org/10.1016/j.cosust.2020.08.012.

Vanbergen, A. (2018). Causes and consequences of pollinator decline. EU Pollinator Initiative Workshop 15/03/2018., BELSPO (Belgian Science Policy Office), Avenue Louise 231, 1050 Brussels. https://ec.europa.eu/environment/nature/conservation/species/pollinators/documents/Session%202%20Adam%20Vanbergen.pdf (accessed on 06 August 2021).

Ypaithros newspaper. (2018, July 2). Problems with beekeepers in the Regional Unit of Evritania. ypaithros.gr. https://www.ypaithros.gr/melisokomia-evritania-authairesia/ (accessed on 06 August 2021).

Zittis, G., Hadjinicolaou, P., Klangidou, M., Proestos, Y., & Lelieveld, J. (2019). A multi-model, multi-scenario, and multi-domain analysis of regional climate projections for the Mediterranean. Regional Environmental Change, 19(8), 2621–2635. https://doi.org/10.1007/s10113-019-01565-w

Investigation of changes in the transport habits in Greece due to COVID-19 pandemic

Athanasios Galanis[1], Dimitra Tsiantoula[2], Nikiforos Botzoris[2], Vassilios Profillidis[2] & Panagiotis Lemonakis[3]

[1]*International Hellenic University, Department of Civil Engineering*
Terma Magnesias, 62124 Serres, Greece
[2]*Democritus University of Thrace, Department of Civil Engineering, Section of Transportation*
Campus Xanthi – Kimmeria, 67100 Xanthi, Greece
[3]*University of Thessaly, Department of Civil Engineering, Section of Transportation*
Pedion Areos, 38334 Volos, Greece
atgalanis@ihu.gr, dimitratsiantoula97@gmail.com, nikibotz@civil.duth.gr, vprofill@civil.duth.gr, plemonak@uth.gr

Abstract

This study examines the possible changes in the transport habits of citizens in Greece, due to the imposition of measures to prevent and limit the contagion of the Covid-19 pandemic, through a questionnaire survey with 755 participants. The questionnaire is divided into three subsections and was distributed electronically using Google Forms. The research focuses on the transport habits, the frequency and the reasons of trips with specific transport modes, in the period before the pandemic. In addition, it analyzes the views of the respondents regarding the changes in the way and the frequency of the trips, the choice of transport modes and their opinion regarding the difference of the traffic volume of the streets, the pedestrian flow and the traffic congestion period during the enforcement of measures in order to prevent the contagion of Covid-19.

The results of this research mainly indicate that the respondents used primarily and secondarily their cars, both before and during the pandemic. In addition, there was a significant reduction in their trips during the period of restrictive measures, the use of public transport was significantly reduced and at the end of the pandemic they will choose to walk for their recreational trips.

Keywords: Transportation; Transport habits; Covid-19; Greece.

JEL Classification: L91; O18; R41.

1. Introduction

The COVID-19 pandemic has seriously affected the life of citizens in Greece and worldwide. The COVID-19 restrictive measures in Greece affected citizens' daily life into a new reality (Government of Greece, 2020). The outbreak was identified in December 2019, in Wuhan, China (Wikipedia) and World Health Organization recognized it as a pandemic in 11 March 2020 (WHO). The COVID-19 pandemic affected seriously the global economy and now attention is turning to the long-run impact of the shock on productivity. Long-term output losses are estimated in the order of 3% of global GDP (Bartholomew & Diggle, 2021). Furthermore, the COVID-19 pandemic could affect the supply side of the economy through several channels and thus lead to a permanently lower level of potential output (Martín Fuentes & Moder, 2021). Digital transformation evolution took place during the COVID-19 pandemic (Zeitelhack, 2020) and digital transformation can be the key to revival after the pandemic (Tse, 2020). During the lockdown period, teleworking and tele-education were based on digital transformation and development of new software tools and skills from daily users. This transition came quickly and its benefits shaped a new world in the areas of work and education. A study from Botzoris et al. (2016) supports that many citizens can telework from their residence using new technological tools. Furthermore, they were willing to increase teleworking in order to save time and transport cost, and work more conveniently and efficiently.

The COVID-19 pandemic has affected citizens' mobility in local, national or international scale. During the years 2020 and 2021 the lockdowns and restrictive measures have affected all passenger transport. Urban trips have decreased but not equally for all transport modes. The COVID-19 pandemic poses a great challenge for contemporary public transportation worldwide (Tirachini & Cats, 2020). Transmission of SARS-CoV-2 is very possible in public transport vehicles because people are in close contact with each other, comparing to private vehicles. The use of sustainable transport modes, especially public transportation, should not be reduced in favor of private vehicles. Especially in Greece that suffered economic depression in previous years, citizens were willing to increase use of sustainable transport modes in order to reduce the transport cost (Galanis et al., 2017).

This study examines the possible changes in the transport habits of citizens in Greece, due to the imposition of restrictive measures in order to prevent and limit the contagion of the COVID-19 pandemic, through a questionnaire survey.

2. Methodology and Data Collection

This study was based on a questionnaire survey conducted during the spring of the year 2021 on a sample of 755 individuals. Participants in this survey answered the questions anonymously and honestly. Clarifications, if necessary, could be given through contact details (email). The questionnaire was divided in three parts and the time to answer the questions was about 10 minutes. The questionnaire was formed in Google Forms and its dissemination was possible through emails, SMS and Viber text messages, and social media.

After the data collection was completed, followed the data analysis and export of results and conclusions. The data were analyzed with the use of Microsoft Excel and the analysis was based on descriptive statistics.

3. Results

The survey results are presented in the following Figures 1-19. In Figures 1-5, are presented the participants demographic data: "Gender" (Figure 1), "Age" (Figure 2), "Residential area" (Figure 3), "Education" (Figure 4), and "Profession" (Figure 5). In Figures 6-11, are presented the results of questions regarding the period before the pandemic: "Frequency of travel with private car" (Figure 6), "Main reason for travel with private car" (Figure 7), "Frequency of travel with public transport" (Figure 8), "Main reason for travel with public transport" (Figure 9), "Frequency of walking" (Figure 10), and "Main reason for walking" (Figure 11). In Figures 12-18, are presented the results of questions regarding

the period during the pandemic, and in Figure 19 after the pandemic: "Have you changed the way that you travel before and during the COVID-19 pandemic?" (Figure 12), "There has been teleworking or tele-education in your work or education environment?" (Figure 13), "There has been an increase or decrease in your daily trips during the enforcement of restrictive measures?" (Figure 14), "What transport mode did you use mainly for your trips?" (Figure 15), "What transport mode did you use secondarily for your trips?" (Figure 16), "What did you notice about the pedestrian flow in the streets during the pandemic?" (Figure 17), "What did you notice about the traffic volume in the streets during the pandemic?" (Figure 18), and "After the end of pandemic and restrictive measures, which of the following actions would be representative to you?" (Figure 19).

Figure 1: Gender of participants

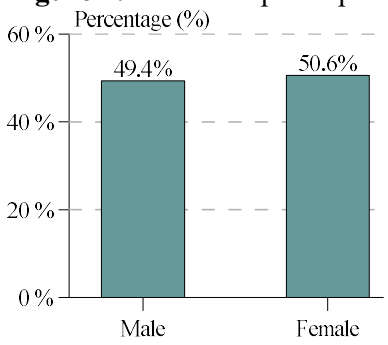


Figure 2: Age of participants

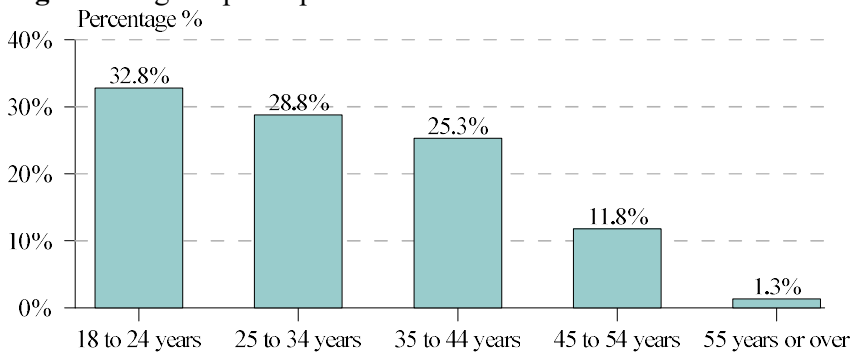


Figure 3: Residential area of participants

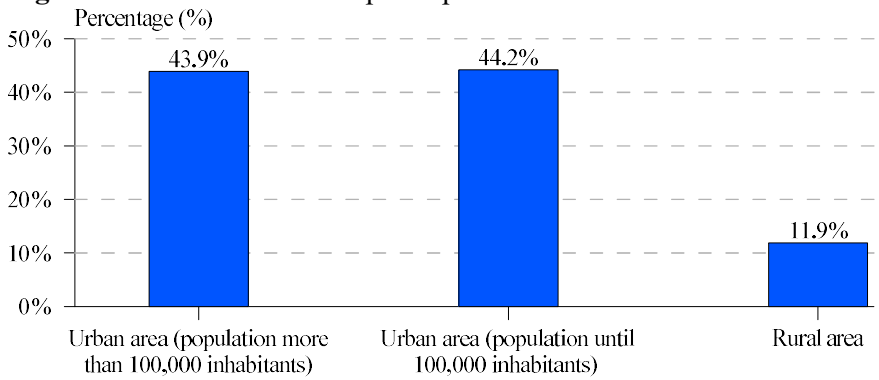


Figure 4: Education of participants

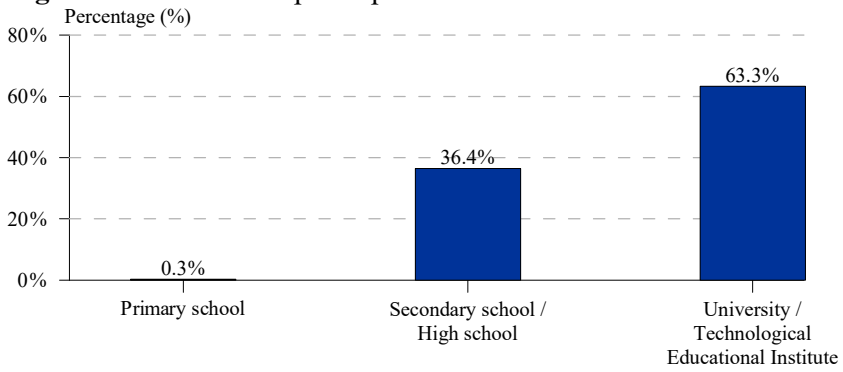


Figure 5: Profession of participants

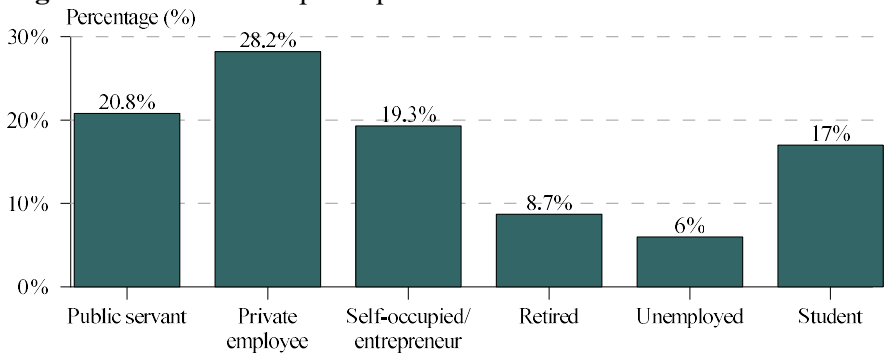


Figure 6: Frequency of travel with private car

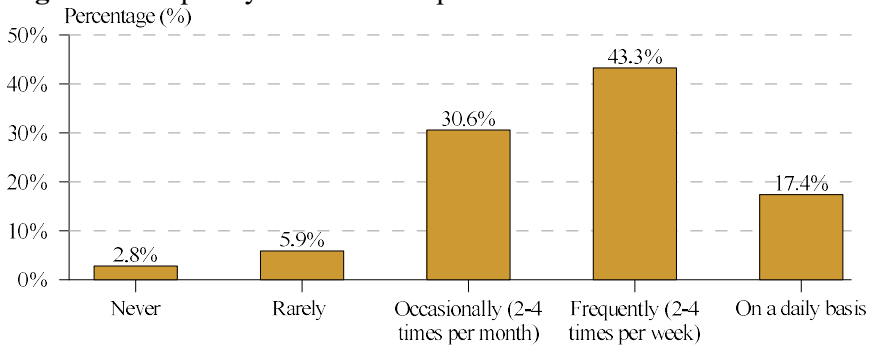


Figure 7: Main reason for travel with private car

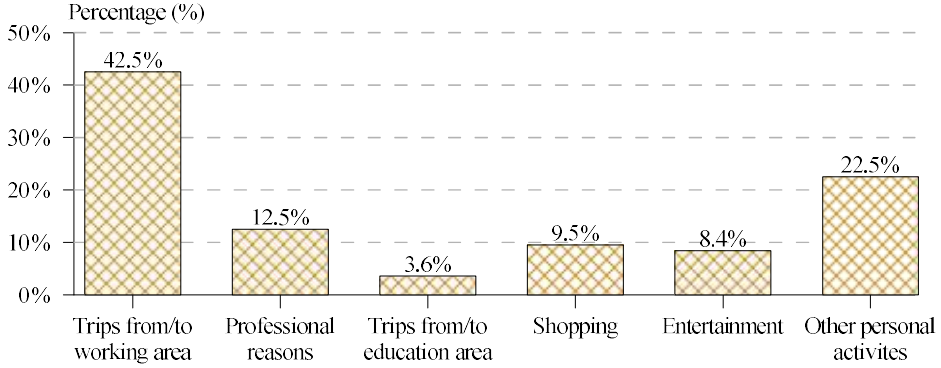


Figure 8: Frequency of travel with public transport

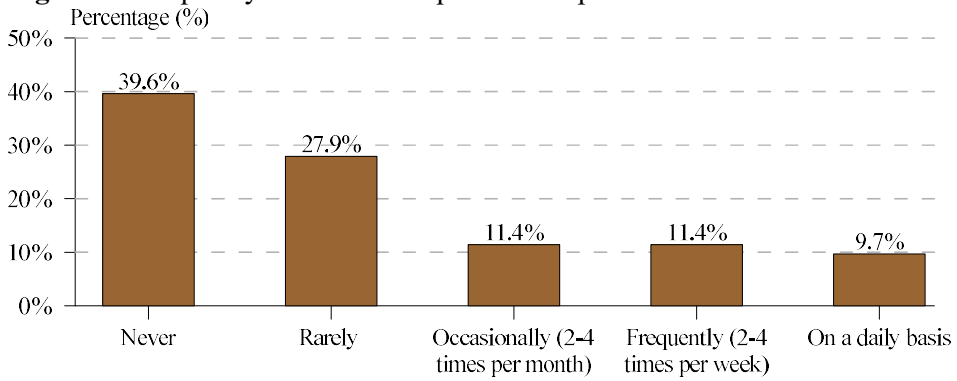


Figure 9: Main reason for travel with public transport

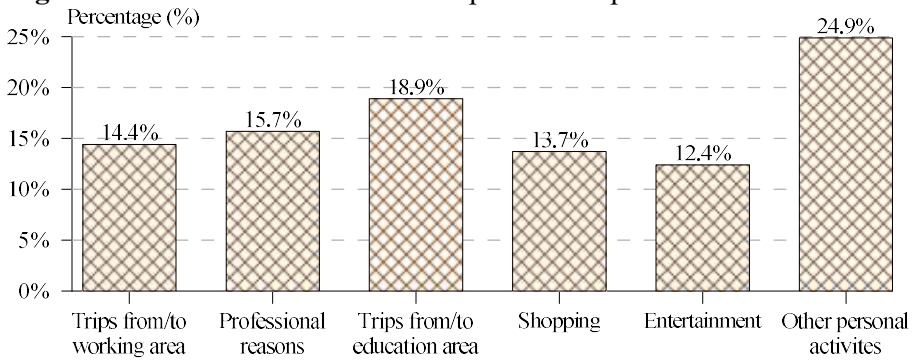


Figure 10: Frequency of walking

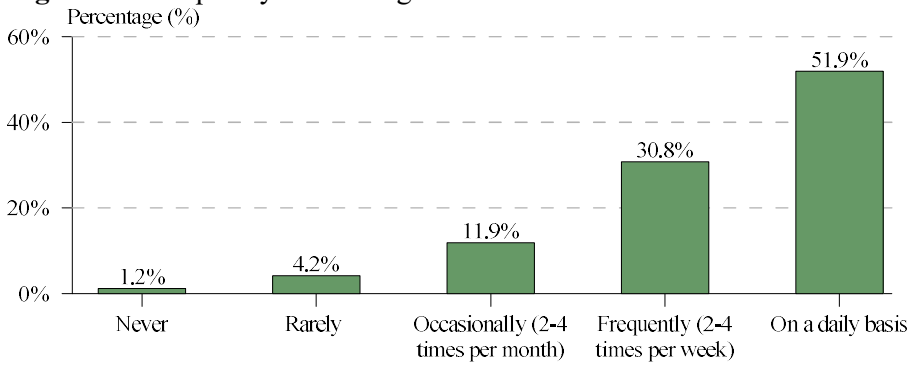


Figure 11: Main reason for walking

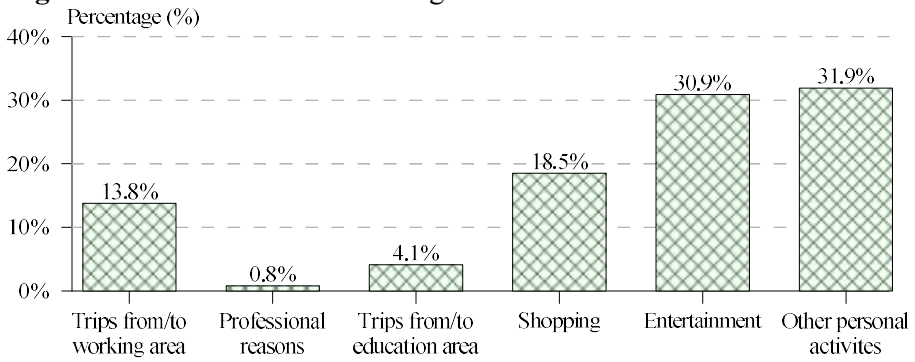


Figure 12: Have you changed the way that you travel before and during the COVID-19 pandemic?

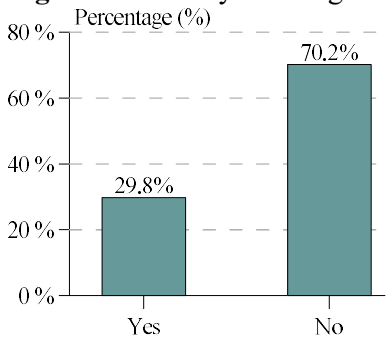


Figure 13: There has been teleworking or tele-education in your work or education environment?

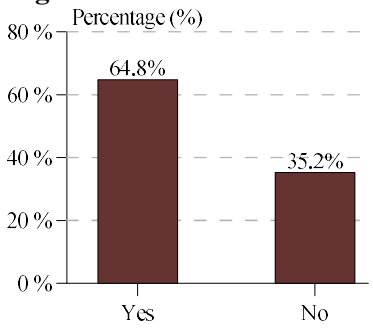


Figure 14: There has been an increase or decrease in your daily trips during the enforcement of restrictive measures?

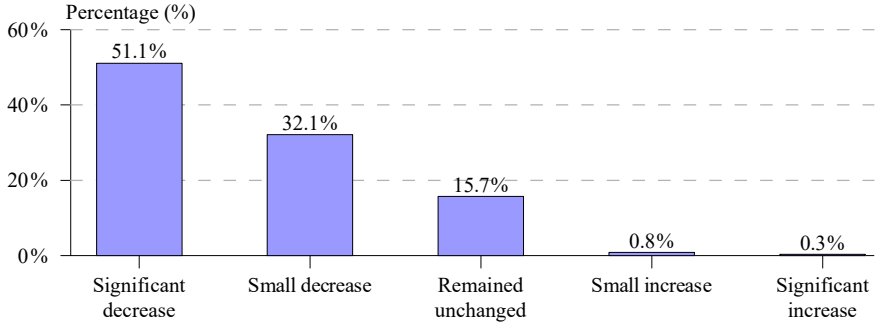


Figure 15: What transport mode did you use <u>mainly</u> for your trips?

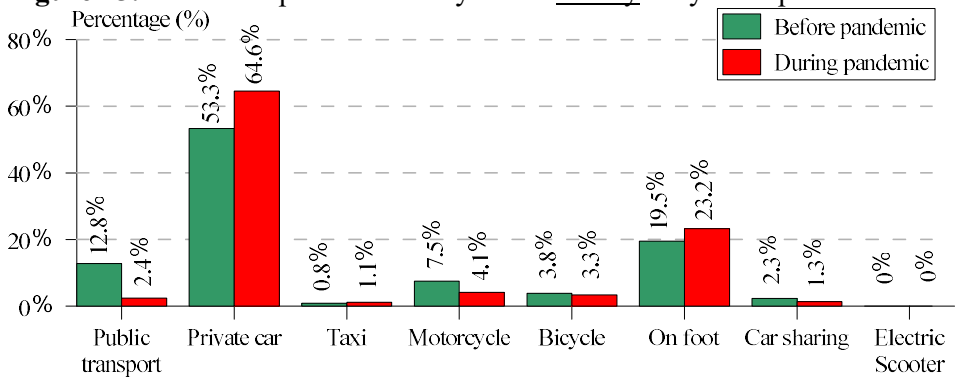


Figure 16: What transport mode did you use secondarily for your trips?

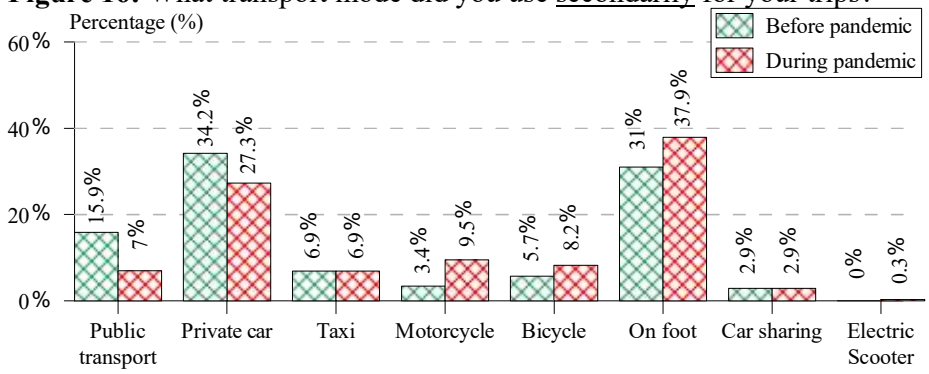


Figure 17: What did you notice about the pedestrian flow in the streets during the pandemic?

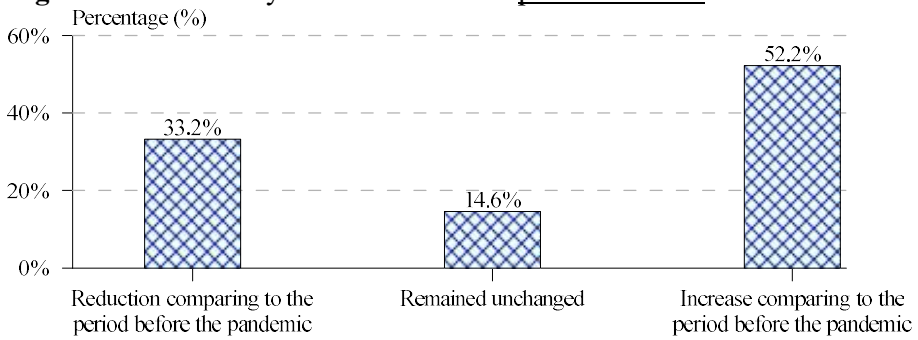


Figure 18: What did you notice about the traffic volume in the streets during the pandemic?

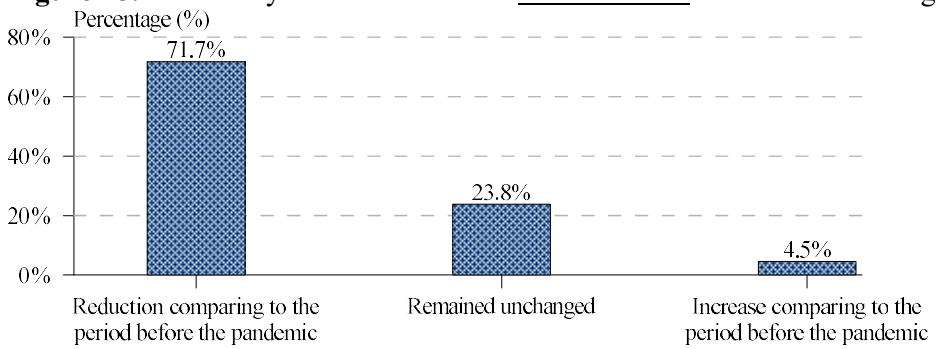
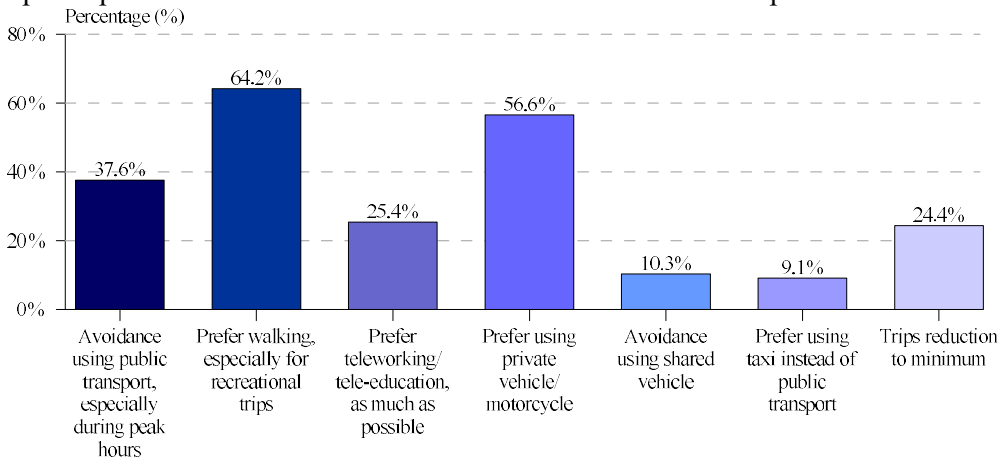


Figure 19: After the end of pandemic and restrictive measures, which of the following actions would be representative to you?
*participants were able to choose more than one of the choices provided.



4. Conclusions

This study examines the possible changes in the transport habits of citizens in Greece, due to the imposition of restrictive measures in order to prevent and limit the contagion of the COVID-19 pandemic. The main conclusions are the following:

- Respondents (43.3%) travelled frequently (2-4 times per week), 30.6% occasionally (2-4 times per month) and 17.4% on a daily basis, with private car (before the pandemic).
- Respondents (42.5%) stated that the main reason for travel with private car was trips from/to working area (before the pandemic).
- Respondents (11.4%) travelled frequently (2-4 times per week), 11.4% occasionally (2-4 times per month) and 9.7% on a daily basis, with public transport (before the pandemic).
- Respondents (14.4%) stated that the main reason for travel with public transport was trips from/to working area (before the pandemic).
- Respondents (30.8%) stated that walked frequently (2-4 times per week) and 51.9% on a daily basis (before the pandemic).
- Respondents (13.8%) stated that the main reason for walking was trips from/to working area (before the pandemic).
- Respondents (29.8%) stated that they changed the way that they travel before and during the Covid-19 pandemic.
- Respondents (64.8%) stated the presence of teleworking or tele-education in the work or education environment.
- Respondents (51.1%) stated a significant decrease of their daily trips during the enforcement of restrictive measures.
- Private cars (64.4%) and walking (23.3%) were the main transport modes during the pandemic.
- Private cars (27.3%) and walking (37.9%) were the secondary transport modes during the pandemic.
- Use of public transportation was reduced comparing the period before (12.8%) and during (2.4%) the pandemic.
- Respondents (52.2%) noticed a pedestrian flow increase in the streets during the pandemic.
- Respondents (71.7%) noticed a traffic volume reduction in the streets during the pandemic.
- Respondents stated that after the pandemic, they will avoid use public transportation (37.6%) and shared vehicles (10.3%), they will reduce trips to minimum (24.4%) and prefer walking

(64.2%), private vehicles/motorcycles (56.6%), teleworking/tele-education (25.4%) and taxi instead of public transportation (9.1%).

This study supports that in Greece citizens mainly and secondarily used their private cars and walked, before and during the pandemic. Furthermore, use of public transportation was significantly reduced comparing the period before and during the pandemic. Additionally, it was noticed a significant reduction of citizens' daily trips and reduction of traffic volume and increase of pedestrian flow in the streets during the pandemic. Finally, the study supports that after the pandemic citizens will avoid use of public transportation (mainly during peak hours) and shared vehicles, they will reduce trips to minimum and prefer walking, private vehicles/motorcycles, teleworking/tele-education and taxi instead of public transportation.

The COVID-19 pandemic changed citizens transport habits. The pandemic enhanced the importance of private vehicles, walking and bicycling and raised concerns about public transportation safety in the criterion of public health. This is very important because use of public transportation can improve sustainability indicators of a city or a studied area. Further research is necessary in order to evaluate the effects of the pandemic in citizens transport habits and the transport sector.

References

Bartholomew L. and Diggle P. (21 September 2021). The lasting impact of the Covid crisis on economic potential. Available from: https://voxeu.org/article/lasting-impact-covid-crisis-economic-potential

Botzoris G.N., Profillidis V.A. and Galanis A.T. (2016). Teleworking and Sustainable Transportation in the Era of Economic Crisis. 5th International Scientific Conference – ICTIC 2016, www.ictic.sk, March 21-25, 2016.

Galanis A., Botzoris G., Siapos A., Eliou N. and Profillidis V. (2017). Economic crisis and promotion of sustainable transportation: A case survey in the city of Volos, Greece. Transportation Research Procedia, 24, 241-249.

Government of Greece (28 April 2020). Plan for the gradual easing of COVID-19 restrictive measures. A bridge of safety toward a new daily reality. Available from: https://covid19.gov.gr/wp-content/uploads/2020/04/Greece-Plan-for-the-gradual-easing-of-COVID-19-restrictive-measures-Introductory-Presentation-28.04.20_EN.pdf

Martín Fuentes N. and Moder I. (5 February 2021). The scarring effects of COVID-19 on the global economy. Available from: https://voxeu.org/article/scarring-effects-covid-19-global-economy

Tirachini A. and Cats O. (2020). COVID-19 and public transportation: Current assessment, prospects, and research needs. Journal of Public Transportation, 22(1), 1-21.

Tse T. (8 July 2020). Digital transformation as the key to revival after the pandemic. Available from: https://www.openaccessgovernment.org/digital-transformation-as-the-key-to-revival-after-the-pandemic/90065/

Wikipedia, The Free Encyclopedia. COVID-19 recession. Available from: https://en.wikipedia.org/wiki/COVID-19_recession

World Health Organization. WHO Director-General's opening remarks at the media briefing on COVID-19 – 11 March 2020. Available from: https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020

Zeitelhack A. (16 November, 2020). The digital transformation revolution during COVID-19. Available from: https://www.openaccessgovernment.org/the-digital-transformation-revolution-during-covid-19/97748/

Mega Infrastructure Projects and their contribution to Sustainable Development The case study of the Athens Airport, Eleftherios Venizelos

Angelos Papavasileiou & Roido Mitoula
Department of Economics and Sustainable Development,
School of Environment, Geography and Applied Economics
Harokopio University of Athens
apapavasileiou@hua.gr , mitoula@hua.gr

Abstract
Large airports are important mega infrastructure projects that promote sustainable development. They contribute to reducing travel and transport times, global economic activity, international trade, and tourism. In addition, they contribute to social development by creating jobs and alleviating regional inequalities, as they make even the most remote and inaccessible places accessible. Especially for areas that are not globally recognised economic centres, the existence of a large airport facilitates access. It attracts investors, employees, and visitors, contributing to strengthening the local economy. In this paper, the positive contribution of airports to the economic development of a place is confirmed. Eleftherios Venizelos Airport is selected as a case study. It is located in Athens, the capital of the Greek State and is the main gateway into the country by air. Through primary research questionnaire material and secondary statistics data of our processing, the impact of the airport on the sustainable development of the wider host region and its contribution to the national economy and development is investigated. The primary research was organised using the Microsoft Forms software and the processing and analysis of the secondary data with the statistical analysis software Stata. The research findings given in the conclusion demonstrate the contribution of this specific mega infrastructure project to local and national sustainable development.

Keywords: Mega Infrastructure Projects; Sustainable Development; Sustainable Infrastructure; Airports and Development; Airport Eleftherios Venizelos; Athens; Greece.

JEL Codes: Q01; Q50; Q56; R11; R40; R42;

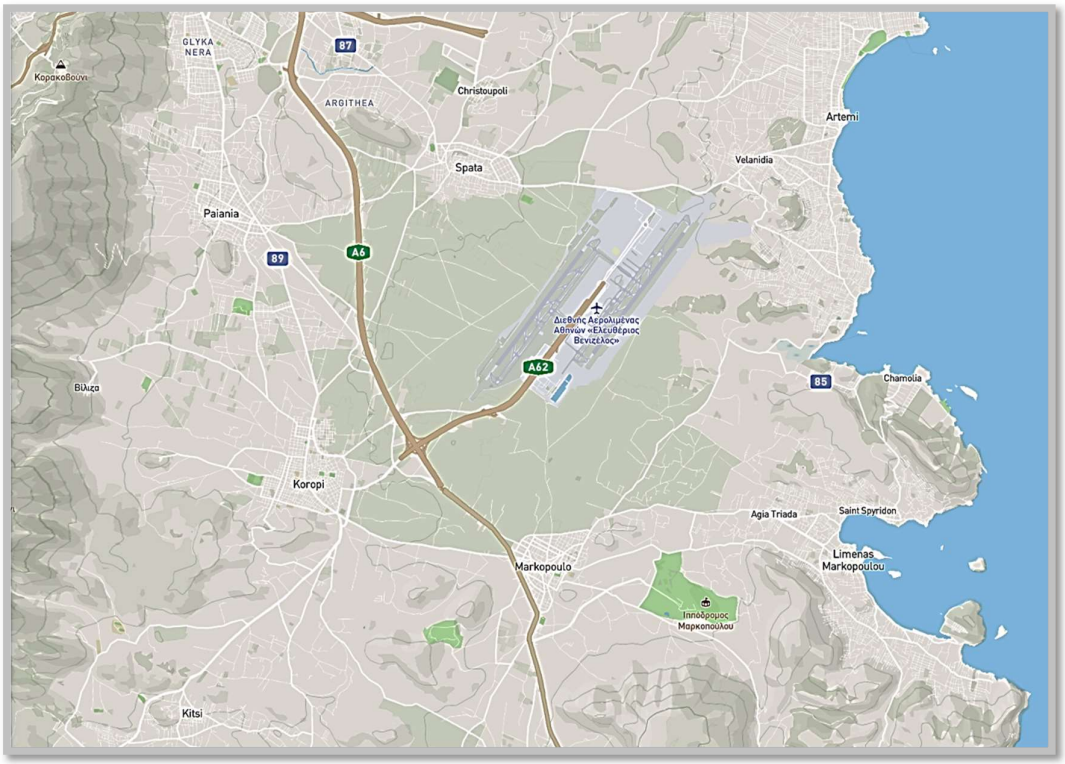
1. Introduction

The operation of large airports is a significant development factor for each country. However, for airports to have an impact on each country's steps and development efforts, they must be connected with the rest of the activities of the productive sectors (tourism, leisure, business offices, conference and exhibition organisations, cargo handling and distribution centres, high-tech industries, etc.) and activate towards the direction and areas in their immediate vicinity. This connection will also attract large airlines and complete their role as hubs for international transport networks and not just as intermediate service stations. Furthermore, due to the liberalisation of transport within the European Union, the airports will operate in a regime of international competition (Mitoula et al. l, 2008).

According to international experience, there are two categories of airports: those that are created to ease the movement of others and which do not have as their primary purpose the modernisation of transport and access to a country and those that are located based on political choice, economic development through business activities that are directly related to their creation (Ginosatis and Genet, 1998). Spata airport belongs to the second as it emerged as a more general development policy decision. In addition, events such as the 2004 Olympics are also crucial to its design. The impact of other airports in this category, always according to international experience, includes changes in the average percentage increase in property prices (in a decade increased by 175% more than in the wider urban area), population growth, and housing growth.

Regarding economic development issues of the airport's broader area, residential areas, local businesses and service providers, aviation activities showed a significant increase in a short period, while in the medium term, i.e. for 15 years, there are multiplier effects on the broader economy. So we conclude that installing an airport in space is associated with many parameters and impacts many areas and functions. Thus, the functions and activities are changed to meet its needs and be integrated and modernised with the new conditions. In many European cities, the airports, near or away from them, did not have any developmental impact on their surroundings, and their relationship with the city is limited to the possible pollution from the aircraft exhaust and the problems of their connection with it. In Greece, however, where land uses are not predetermined and controlled, the creation of the new airport was accompanied by numerous changes and affects -spatial and non-spatial- which are all part of the urban land use. (Mitoula et al. l, 2003)

Map 1. Athens International Airport Eleftherios Venizelos



Source: Google maps

2. Eleftherios Venizelos Airport

Eleftherios Venizelos Airport, one of the most modern airports in the world located in the Mediterranean region, in Spata, is the result of pioneering cooperation between the Public Sector and the private initiative. About 16 to 19 million passengers per year travel using Eleftherios Venizelos Airport. It consists of two parallel runways that allow simultaneous take-offs and aircraft landings and contains a complete aircraft tracking system to serve the two runways. It also accepts up to 65 aircraft movements per hour has 73 aircraft parking spaces and 24 passenger boarding bridges. In addition, it contains 13 luggage collection units and 3200 parking spaces. The airport has a main terminal, a satellite, and two paved runways, the 03R / 21L with a length of 4000m. long and 45m. width and the 03L / 21R with a length of 3800m. and width similar to 03R / 21L. Both corridors have an ILS system. In addition to ILS, there are a variety of systems for handling airport operations.

In 1996, the Legal Entity of Private Law "Athens International Airport SA" was created, a company responsible for the construction and operation of the airport for a total period of 30 years. Athens International Airport "Eleftherios Venizelos" serves the city of Athens. It started operating in March 2001 and replaced the Hellinikon International Airport, which served Athens for about 6 decades. It was named in honour of the great Cretan politician Eleftherios Venizelos, who, as prime minister, established the Ministry of Aviation and was the first to try to organise Civil Aviation in Greece. (Prastakos et al., 2009).

The first plans to transfer the Airport from Elliniko to another location began as early as the late 1960s when Athens began to expand, with the result that the old airport was surrounded. The idea was maintained even after the Metapolitism; in 1976, a study was presented to the Greek Government that indicated Spata as an ideal location for a new airport. However, as Greece entered a period with many internal and external problems, the project was abandoned. In the early 1990s, it was now evident that Elliniko could not serve the increased passenger needs of the future unless it expanded. As this was no

longer possible, and in parallel with the intense protests for noise pollution and high risk of increasing, the Greek Government decided to move the airport to an area outside the city.
The location remained the same, and on July 31, 1995, after an international tender, the German company Hochtief was selected for its construction and subsequent co-ownership with the Greek State. As a result, the Greek government and the private consortium concluded the Airport Development Agreement (SAA), ratified by Law 2338/1995. The purpose of this contract was the development of an international airport in Spata, through a cooperative scheme of the Public and Private sector, with the BOOT method, i.e. the process that includes four stages of construction, ownership, operation and transfer. The private sector included three shareholders with a total percentage of 45%, while the public sector owned 55% of the shares of Athens International Airport (Prastakos et al., 2009).
The cost of building the airport is about two billion euros. Finally, to summarise the project, the critical dates of its development are as follows: 1995 (when the contract was signed), 1996 (where the foundation ceremony took place), 1997(where the construction began), 2001 (when the airport started operating) and 2000 (where the construction phase was completed and the test period began) (Prastakos Mr. a., 2009).

3. Research methodology

A study with questionnaires was undertaken for the demands of the work between November 2020 and April 2021. The sample included 317 residents of the Attica Region. Given the movement restrictions caused by the COVID-19 epidemic. The research findings were organised and processed using the open free Microsoft forms application. The Stata statistical tool was used to analyse the data. The questionnaire includes questions about the airport's impact on the environment, the economy, and social life in Athens. Due to COVID-19, the approach employed to conduct the research is to send and complete 27 questions using social media. Facebook and email were the most commonly used modes of communication. Users of Eleftherios Venizelos Airport in Athens were the focus of the study. In addition, permanent residents of Attica's urban and suburban districts were given preference in the research because of their extensive experience using and influencing the project in their respective work and residence zones. As a result, people were more likely to notice the influence of this massive infrastructure project on their daily lives. Individuals of any occupation or professional status were considered eligible to participate in the survey, as long as they were permanent residents of the project's target areas.

The following are the four (4) primary research questions about sustainable development that were chosen to be statistically analysed and correlated with the demographic features of the respondents:

- **Sustainability:** *Did the surrounding Prefectures/Municipalities/Areas develop or generally benefit from the operation and construction of the project?* The question will direct data gathering on the advantages of infrastructure for authorities on the project site. The inquiry aims to comprehend the advantages of significant infrastructure initiatives, such as Sustainable Development. (InterAmerican Development Bank, 2018)
- **Society:** *In your opinion, has residents' quality of life in the area surrounding the project improved?* The question examines the effect of infrastructure on the overall quality of life. The key features are developing jobs, promoting social possibilities, and providing services to people. (Fischer and Amekudzi, 2011)
- **Economy:** *In your opinion, was there an increase in trade in the broader project area?* The growth in commerce determines the project's prominence and influence in the region's economic development, with immediate societal consequences. Thus, improving business through an infrastructure project fosters economic and social prosperity while also contributing to general well-being. As a result, this response will aid in determining the importance of infrastructure in economic development. (Calderon Cesar, Serven Luis, 2004)
- **Environment:** *Did the project contribute positively to the environmental impact of the surrounding areas?* The statement will be a deciding factor in the environmental impact of infrastructure. The

expected responses to the statement were yes or no, which will help measure the project's worth in promoting environmental sustainability. (OECD, 2019)

4. Statistical Analysis

Using statistical analysis of project users' responses, we were able to identify and approach sustainable development theory. We looked for correlations and developed types of regression analysis that explored the statistical significance and statistical prediction, and we were able to conclude. Based on the following regression type:

Formula

$$Y_i = f(X_i, \beta) + e_i$$

We established the key pillars of sustainable development (Figure 1) as dependent variables (Yi), which we investigated using specific questionnaire questions referred to in paragraph 3. We included demographic data and the pillars of sustainable development as independent variables (Xi) in the equation (gender groups, level of education, work background and other principles of sustainable development other than the one we consider each time as a dependent variable).

Finally, **4 distinct forms of regression analysis** were identified using **14 independent variables.**

- **Environment**

Environment=β_0+β_1 Commerce+β_2 Quality of life+Demogr.β+ε_1 **(1)**

- **Economy**

Commerce=γ_0+γ_1 Environment+γ_2 Quality of life+Demogr.γ+η_1 **(2)**

- **Society**

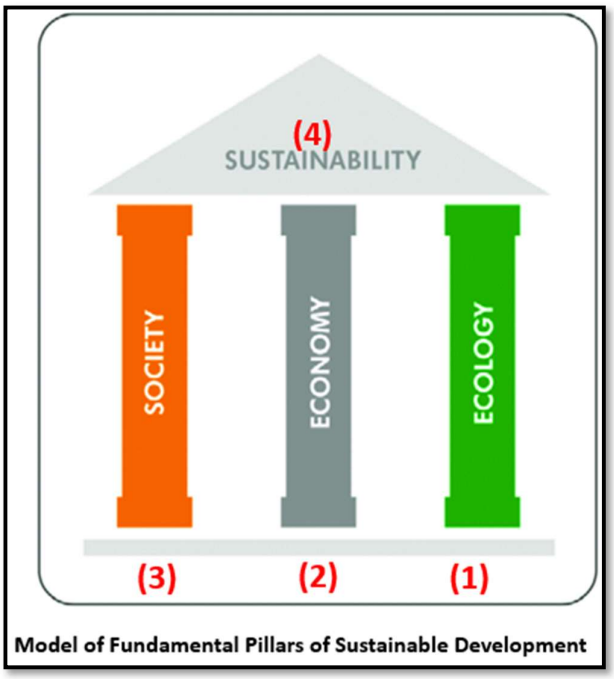
Quality of life=δ_0+δ_1 Environment+δ_2 Commerce+Demogr.δ+φ_1 **(3)**

The relationship between the three fundamental pillars and Sustainable Development:

- **Sustainability**

Growth=λ_0+λ_1 Environment+λ_2 Commerce+λ_3 Quality of life+Demogr.λ+θ_1 **(4)**

Figure 1. The interaction between the three fundamental pillars of Sustainable Development in Mega Infrastructure Projects



5. Statistical Model Analysis Results

Table 1: Definitions

Variable name	*Definition*
Area_Growth	*Did the surrounding Prefectures / Municipalities / Areas have been developed or generally benefited from the operation and construction of the project?*
Commerce	*In your opinion, was there an increase in trade in the broader project area?*
Qual_life	*In your opinion, has the quality of life of residents in the area surrounding the project improved?*
Environment	*Did the project contribute positively to the environmental impact of the surrounding areas?*

Table 2: Descriptive Statistics

Variable	*Mean*	*Std. Dev.*	*Min*	*Max*
area_growth	**0.9242902**	**0.2649514**	0	1
environment	**0.3091483**	**0.4628731**	0	1
qual_life	**0.7917981**	**0.4066639**	0	1
commerce	**0.9179811**	**0.2748274**	0	1
female	0.6340694	0.4824517	0	1
age18_28	0.4984227	0.500788	0	1
age29_39	0.2618297	0.4403255	0	1
age40_50	0.1167192	0.3215931	0	1
age51_60	0.1104101	0.3138957	0	1
University	0.5488959	0.4983902	0	1
single	0.70347	0.4574495	0	1
married	0.2334385	0.4236877	0	1
unempl	0.1041009	0.3058743	0	1
selfempl	0.0977918	0.2975025	0	1
emplpub	0.1829653	0.3872494	0	1
emplpri	0.214511	0.4111317	0	1
student	0.3343849	0.4725209	0	1

Table 3: Correlations

	area_growth	*commerce*	*qual_life*	*environment*
area_growth				
commerce	0.2187*			
qual_life	0.3525*	0.3281*		
environment	0.0366	-0.0239	0.1917*	

Note: Asterisk (*) denotes statistical significance at 5%

Table 4: Regression analysis

	(1) *qual_life*	(2) *environment*	(3) *commerce*	(4) *area_growth*
	b/se	b/se	b/se	b/se
qual_life		0.274***	0.201***	0.191***
		(0.060)	(0.058)	(0.062)
environment	0.180***		-0.051	-0.000
	(0.040)		(0.034)	(0.024)
commerce	0.385***	-0.148		0.089
	(0.097)	(0.096)		(0.085)
female	-0.036	0.002	0.027	0.024
	(0.042)	(0.056)	(0.030)	(0.028)
age18_28	0.296	-0.715**	0.001	0.221
	(0.247)	(0.290)	(0.196)	(0.198)
age29_39	0.343	-0.549*	0.021	0.230
	(0.243)	(0.287)	(0.192)	(0.197)
age40_50	0.289	-0.221	0.003	0.278
	(0.239)	(0.293)	(0.191)	(0.194)
age51_60	0.363	-0.347	0.007	0.308
University	0.196***	-0.149**	0.005	0.041
	(0.056)	(0.066)	(0.041)	(0.034)
single	-0.017	0.142	0.128	0.135**
	(0.061)	(0.122)	(0.078)	(0.064)
married	0.002	-0.051	0.132**	0.031
	(0.058)	(0.128)	(0.065)	(0.057)
unempl	-0.080	0.115	-0.019	-0.034
	(0.098)	(0.130)	(0.074)	(0.061)
selfempl	-0.004	0.055	0.038	0.009
	(0.083)	(0.145)	(0.057)	(0.054)
emplpub	-0.081	-0.056	0.063	0.063
	(0.078)	(0.140)	(0.060)	(0.048)
emplpri	-0.042	0.116	0.063	-0.005
	(0.076)	(0.118)	(0.053)	(0.047)
student	-0.104	0.068	-0.024	0.017
	(0.091)	(0.118)	(0.059)	(0.052)
_cons	0.065	0.729***	0.608***	0.301
	(0.249)	(0.274)	(0.210)	(0.196)
N	317	317	317	317
R-sq	0.2576	0.1260	0.1525	0.1890

Note: Asterisks *, ** and *** denote statistical significance at 10%, 5% and 1% respectively

6. Research of Secondary Data

According to the sustainable development reports of Athens International Airport Eleftherios Venizelos, published on the official airport's site, the data we collected and analysed are related to Economic, Environmental and Social Performance. (aia.gr)

Table 5: Comparative Data of Sustainable Development and Social Responsibility

Comparative Data of Sustainable Development and Social Responsibility Athens International Airport Eleftherios Venizelos						
Year		**2005**	**2010**	**2015**	**2018**	**2019**
Passengers	*Millions*	14.3	15.4	18.1	24.1	25.6
Revenue	*Millions*	269.3	406.4	403.4	495	518.5
Corporate responsibility % of total operating expenses	*%*	1.3	2.73	2.92	2.56	2.65
Social Product	*Millions*	86.9	157.5	106.9	187	208.8
Investments in Local Communities	*Thousands of euros*	125	301.8	229	359.4	462.6
Investments in arts and culture	*Thousands of euros*	15	126.6	495	311.6	350
CO2	*Tones*	65	54.71	38.5	39	43
Waste	*Tones*	8.378	12.669	11.081	39.221	19.861
Recycling	*Tones*	1.713	5.01	5.737	6.607	12.734
Energy Consumption	*MWh*	140.025	129.173	100.396	109.796	113.336
Water Consumption	*Tones*	710	667	604	642	647

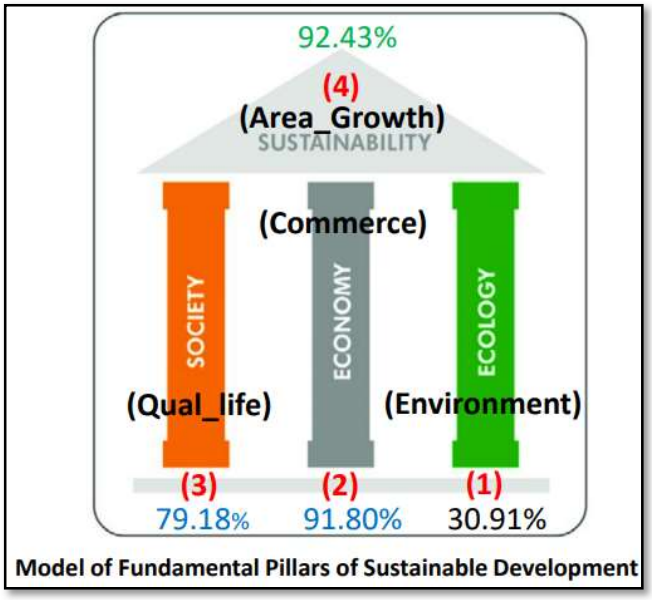
Data Source: Collected by AIA Annual Sustainability Reports

7. Discussion

As a result of the statistical analysis model that we created and assessed, we came to the following first and most evident and crucial conclusion, verified by the correlation table 3 and the regression analysis table 4. After carefully observing and analysing the results of descriptive statistics, correlations, and statistical regression analysis, it becomes clear that the quality of life (Qual life), which we have defined as the pillar of society in the theoretical model of sustainable development, is positively correlated with the achievement of sustainability. Furthermore, following the results of the descriptive statistics (Table 2), all questions regarding the positive influence of the Athens International Airport project, which we established as the critical pillars of the statistical model for sustainable development, have high approval rates.

The question on Improving Quality of Life (Qual life) received 79.18 percent of the vote, while the question on Commerce Development got 91.80 percent. The question on the Environmental Impact of the airport received 30.91 percent of the favourable vote. However, this result creates scepticism about how well the environmental performance of AIA has been communicated to the public, taking into account the secondary data that has been examined, which was very positive. In addition, the project's positive contribution to the development of the project areas received 92.43 per cent of the vote (Area_Growth) 92.43% (Figure 2).

Figure 2



The statistical regression analysis of the model (Table 4) and the correlation control (Table 3) were used to decode trends and predict positive responses. We found out that the quality of life variable (Qual_life), which represents the pillar of society, mutually reinforces all the other pillars that we set, namely the Environment (environment), the Economy (commerce) and Sustainability (Area_growth). In addition, we see that the improvement of quality of life (Qual_life) interacts favourably with both the independent and dependent variables, which is a notable finding given the importance of our study issue.Additionally, we show that the university graduates group is more likely to respond positively to the impact of the Athens International Airport on increasing quality of life, whilst the education level group is susceptible to quality of life issues. On the contrary, the regression analysis shows that respondents who are in the age groups 18 to 28 (age18_28), the 29 to 39 (age29_39) and the education level group of university-educated (University) are less likely to answer positively to the question of the Environment (environment), and this can be justified considering that these ages groups are more sceptical and more sensitised related to the environmental issues. Finally, regarding the statistical analysis of the Economy (commerce) regression analysis, we observe that the married group is likely to answer that the project contributes positively to the economy of the areas in which it runs. At the same time, the group of respondents with a single status (single) is likely to respond positively to the project's positive impact on Sustainability(area_growth).

Finally, it is worth noting that the comparative analysis of secondary data (Table 5) from the sustainable development reports of AIA gave significant observations. The data show that from 2005 until 2019, we observed an increase of 11.3 million visitors; moreover, 2019 was when the passenger number peaked (25.6 million passengers). Furthermore, in the same period, it is worthful to mention that the yearly overall social product that AIA offers to the national economy of Greece increased by 121.9 million (starting from 2005 from 86.9 million and ending with 208.8 million in 2019). In addition, of course, it is vital to mention that the investments in the local communities around the Eleftherios Venizelos Airport started with 125.000 euros per year and finalised with 462.600 per year in 2019. In addition, by diving deep into the comparative environmental numbers, the CO2 performance of the AIA began in 2005 with 65 tons of CO2 emissions with 14.3 million passengers and finalised with 43 tons of CO2 with 25.6million passengers in 2019. Moreover, with the same trend of the numbers, we find at the Energy consumption that started at 2005 with 140.025 MWh and finalised with the incredible number of 113.336 MWh at 2019 considering the increase of the passengers that we noted in the above comparative numbers.

Last but not least is the observation of Noise, Air pollution and surrounding local communities complaints numbers that are monitored from the AIA have been in place since the airport opened, implemented in collaboration with the Hellenic Civil Aviation Authority (HCAA) and airlines to reduce noise in the residential areas around the airport. The published data from the last years show us that the

airport works and monitoring these crucial environmental parameters and the impact on the environment and in the local communities where are minimal according to the international standards.

8. Conclusions

According to the statistical research analysis and the comparative analysis of secondary data collected, Athens International Airport Eleftherios Venizelos contributes significantly to the sustainable development of Greece, Athens, and the surrounding areas, neglecting the negative impacts of a project of this size can have on rural areas. In addition, its reputation is contributional to the general public and the citizens who use it and benefit from it in various ways, as shown in the preceding paragraphs.

The research results revealed apparent replies in the questionnaire's selected questions (Table 1) utilised in the statistical analysis model. First, the vast majority of respondents felt that the project's affected areas have been developed and benefited in general due to the AIA's construction and continuous presence. As a result, they respond positively to the project's sustainability pillar. Moreover, according to the study's findings, most respondents stated that the Athens Airport Eleftherios Venizelos helped expand business in the surrounding areas by responding to the economy's crucial pillar. Furthermore, respondents provided strong opinions on whether the quality of life of people in the surrounding areas, which acts as the research's pillar of the Society, has improved at the same time.

As a result, the contribution of the Eleftherios Venizelos International Airport is favourable in terms of the environmental impact of the surrounding areas, as indicated by the pillar of Environment in the statistical model. Furthermore, the survey findings again demonstrated exceptionally high percentages of acceptability by those who participated. Therefore, the presence of the AIA in the surrounding towns has relieved many of the concerns that have been previously discussed, and many of these areas have become some of the most popular locations to relocate.

Additionally, the Eleftherios Venizelos Airport has improved people's living conditions due to the increased flow of passengers that it transports daily, remodelling the surrounding areas and contributing economically, either indirectly or directly, to the local economy and Society. Nevertheless, we believe that the current research on the contribution of large infrastructure projects to sustainable development requires a significant amount of analysis, and the goal is to continue with further investigation of the statistical model, enriching it with secondary statistics from organisations and statistical services, as well as independent and dependent formulas for the fundamental pillars of Sustainable Development. The ultimate goal is to construct a trustworthy statistical model that can be used to analyse the influence of significant infrastructure initiatives on long-term economic development.

References

Calderon Cesar, Serven Luis, (2004) "The effects of infrastructure development on growth and income distribution" (English). Policy, Research working paper; no. WPS 3400 Washington, D.C.: World Bank Group.

Fischer, Amekudzi, (2011) "Quality of Life, Sustainable Civil Infrastructure, and Sustainable Development: Strategically Expanding Choice", ASCE, Journal of Urban Planning and Development/Volume 137 Issue 1 - March 2011

Gkinosatis, C. and Gene, Th., (September 1998), Growth prospects and trends in the banking system - The case of the area of influence of the airport "Eleftherios Venizelos", Panteion University, Athens

Inter-American Development Bank, IDB Invest (2018), "What is Sustainable Infrastructure? A Framework to Guide Sustainability Across the Project Cycle", IDB Technical Note; 1388

Mitoula R., Economou Ag. (2008) "Regional Development and environmental protection in Greece", Studies in REGIONAL & URBAN PLANNING (SRUP) Journal, p. 145-159, 11b Issue, December 2008

Mitoula R., Patargias P. Abeliotis K. (2003) "The Transportation Efforts in the City of Athens Towards Environmentally Friendly Transportation", 39th Isocarp International Congress - Cairo Egypt. October 2003

OECD (2019), "OECD Reference Note on Environmental and Social Considerations in Quality Infrastructure". G20 Presidency of Japan Infrastructure Working Group

Prastakos, G., Vonortas, N., Kostopoulos, K., & Stromplos, N. (2009). The contribution of Athens International Airport to the Greek economy. Analysis & Measurement of the Economic Impact of Athens International Airport "Eleftherios Venizelos" on the Greek Economy. Athens: Athens University of Economics and Business.
https://www.aia.gr/company-and-business/the-company/Corporate-Publications/annual-report

Driver distraction of cyclists in urban environment: A methodological approach

Dimitrios Kontos[1], Panagiotis Lemonakis[1], George Botzoris[2], Athanasios Galanis[3] & Nikolaos Eliou[1]

[1]University of Thessaly, Department of Civil Engineering, Section of Transportation
Pedion Areos, 38334 Volos, Greece
[2]Democritus University of Thrace, Department of Civil Engineering, Section of Transportation
Campus Xanthi – Kimmeria, 67100 Xanthi, Greece
[3]International Hellenic University, Department of Civil Engineering
Terma Magnesias, 62124 Serres, Greece
dimikontos@uth.gr, plemonak@uth.gr,
gbotzori@civil.duth.gr, atgalanis@ihu.gr, neliou@uth.gr

Abstract

Undoubtedly, road accidents are a public health problem, the impact and importance of which have increased in recent decades. Road safety data have systematically shown how cyclists are very vulnerable to being involved in a car accident and suffering serious injuries resulting from it. Furthermore, although the data are still very limited, in addition to the other human factors involved in cycling accidents, distraction when using the bicycle seems to contribute significantly to the road risk of riders.

It is well known that driving is a complex process that requires the simultaneous existence of physical, mental and sensory abilities. Despite the complexity of driving, it is observed that drivers deal with things that are irrelevant to the driving task. And this is a huge problem in transport safety, the distraction of the driver. With the growing number of portable devices as well as the electronic help and entertainment systems offered to the driver, the sources of distraction are constantly increasing. The purpose of this study is to understand the phenomenon of driver distraction and to export results, important for the progress in dealing with the phenomenon by the various agencies that can be used as a basis for further research. More specifically, a summary of the recent literature on driver distraction is made, focusing specifically on the distraction of drivers, both by technological means and by external factors.

Finally, a methodological approach is applied to the phenomenon, and in particular to the distraction of the bicycle driver in the urban environment, which includes the realization of an experiment in real conditions in the city of Volos. The research involved 15 drivers, who were asked to perform a specific route by cycling and following specific instructions through a navigator. The data collected were analyzed and showed that the phenomenon of driver distraction is real and is a high-risk factor.

Keywords: Road safety; cyclists; driver distraction; distraction sources; navigation.

JEL Classification: R41; R42; O18.

1. Introduction

Given the great importance of urban mobility and transportation as key parts of people's daily lives, road safety is an essential element of social well-being. At the same time, road accidents pose a very serious threat to public health as more than 1.3 million people worldwide die each year as a result of road accidents, making road accident injuries the leading cause of death worldwide. In this regard, transportation dynamics are constantly changing, and different alternative modes of transportation are forcing us to reconsider the role of road safety as a mainly vehicle/infrastructure-related issue, increasing our awareness of accident causes and related intervention with the goal of preventing negative safety outcomes for road users, based on human factors research (Montoro et al., 2000; Cooper et al., 2009; Porter, 2011). However, most of the available transport safety research was based on motor vehicles and their users, without considering that many factors affecting road safety also depend on those who choose to use alternative means of transport such as bicycles.

Road accidents involving cyclists, especially in recent years, have raised concerns among public health organizations and road safety officials. Given the complexity of cycling work and the often-problematic interactions of bicycles with heavier vehicles, with other road users, but also with road infrastructure, one of the factors necessary for the well-being of cyclists is to maintain their attention focused during their travels, on the driving work they have to perform, thus dealing with the unforeseen dangers and demonstrating the safe driving behaviors required by the use of the bicycle. In other words, cyclists' attention should not be distracted while riding.

This study was conducted in a need to approach the effect of driver distraction on bicycle riders. In order to achieve this, an experiment was conducted at a specific route in the city of Volos, Greece. In this field test, a group of fifteen volunteer bike riders were asked to follow a route while receiving auditory and optical instructions from a navigating application. Collected data were analyzed. The results of the experiment performed, showed that the phenomenon of driver distraction is real and is an important factor in causing road accidents in urban environments. Bicycle riders distracted their attention away from the road many times and for multiple seconds. Findings also showed that participants who are also bicycle users, turned their eyes away from driving-related activities for a longer period, compared to those who do not use a bicycle. In contrast, riders who were less familiar with navigating were observed to have shorter distraction times.

2. Literature Review

Studies on the effects of distraction while driving have used various definitions. It is also common not to translate the term of driver distraction accurately. This has to do with the nature of the word distraction. The meaning of the word is relatively vague, without having the necessary precision needed for its scientific analysis. The word distraction in the dictionary is defined as "the distraction of the mind, attention, etc. from a particular object - the fact where one's concentration or attention is disturbed by something." We therefore understand that the general meaning of the word cannot include the complexity of the concept of "distraction" when referring to driving.

As pointed out by Pettitt et al. (2005), there is great diversity among surveys regarding the term "driver distraction" and many of them are done without first defining the structure of the term. According to them, the concept of driver distraction is an everyday term that tends towards something abstract and is not precise enough to be used for scientific purposes. So, this diversity in the definition can become problematic. Nevertheless, it is understandable that different definitions come from different purposes. Many definitions focus on the structure of attention, as well as its distribution, describing the process by which distractions affect drivers. Distraction is related to the process of distribution of attention. Also, several definitions take into account the outcome, such as how much it affects the reaction time, the position on the road, the risk of an accident or driving safety. Defining distraction only with specific results is problematic, because the existence of distraction or not will depend on a random selection of combinations of road events. Various definitions of driver distraction that have been formulated are:

- Shifting attention away from stimuli critical to safe driving to other non-driving ones (Streff and Spradlin, 2000).
- Occurs when any activity distracts the driver from the driving activity (Ranney et al., 2000).
- Driver distraction involves objects or events, both inside and outside the vehicle, that are used to divert attention away from the driving task or to capture the driver's attention, leaving not enough resources to perform correct driving (Manser et al., 2004).
- Driver distraction can be defined as a misallocation of attention (Smiley, 2005).
- It is any activity or process that adversely affects a driver's ability to process information related to safe driving (Sheridan, 2004).

The following definitions were used to characterize driver distraction based on the failure of human functions as factors that have a role in road accidents:

- Driver distraction occurs: "whenever a driver delays in recognizing the necessary information needed to carry out his driving task safely, because an event, an activity, an object or a person, inside or outside his vehicle has forced or tended to cause the driver to be distracted from driving task" (Treat, 1980)
- Driver distraction results "from interference between a driving task and an external stimulation without link with driving (e.g., guide a vehicle and tune the radio). This secondary task can be gestural or visuo-cognitive" (Hoel et al., 2010)
- "Driver distraction is a diversion of attention away from activities critical for safe driving toward a competing activity" (Lee et al., 2008)

It is therefore observed that some definitions describe distraction in terms of its effect on driving performance, others describe it in terms of activities or objects that lead to distraction, and most describe it as something that disrupts the driving task. An approach to formulating a well-established definition of driver distraction was made at the 1st international Conference of Distracted Driving, which took place in Canada in 2005, and defines it as: "a diversion of attention from driving, because the driver is temporarily focusing on an object, person, task or event not related to driving, which reduces the driver's awareness, decision making ability and/or performance, leading to an increased risk of corrective actions, near-crashes, or crashes" according to research by Hedlund et al. (2005).

At a time when multimedia technology systems and driver-assistance systems are becoming increasingly ubiquitous, the likelihood of additional form of driver distraction appearing is considerable. Interacting with all these services is now considered part of the driving procedure. Driver distraction can be caused by a variety of modern technology, including cell phones, heads-up displays, smartwatches, and smartglasses, as well as the navigation systems investigated in this study.

Navigator is now one of the most popular driver aid systems on the market. The goal is to give the driver all the information about a route that is available. As a result, it might be deemed highly effective in terms of improving driver performance, particularly on roads he is unfamiliar with. Furthermore, most navigation systems include dynamic route assistance, which selects the optimum path for the driver (eg avoiding high-traffic roads). Drivers must first enter their destination, after which the system will display the shortest route to that location. The system will then show them turn-by-turn directions and directions on how to get to that destination. In terms of human-driver interaction, navigation systems come in a variety of forms. Some are pre-installed in the vehicle (typically from the manufacturer) and consist of a screen that is placed in the centre of the dashboard. Other devices are frequently mounted to the windshield as separate devices. Smartphones, which come with a variety of navigation apps, are also popular.

Knapper et al. (2015) used in-vehicle naturalistic driving to examine the usability of portable navigation systems in ordinary automobile driving. Seven female and fourteen male experienced users of navigation systems were supplied with a specially geared car for a month. Four cameras, GPS data, and other sensor data were used to document their journey. Participants spent roughly 5% of their journey time dealing with the navigation system, and there was a modest increase in incidences of speeding and they drove

at slightly faster speeds when the navigation system was enabled. They came to the conclusion that the findings provided insight into how and when drivers utilize navigation devices. They claim that, while drivers control their use of such technologies to some level, they frequently engage in unsafe behavior while driving. Christoph et al. (2013) performed a naturalistic driving research on the usage of mobile phones and navigation systems while driving a car. 21 drivers were requested to drive a car for 5 to 6 weeks and operate the vehicle and equipment as they normally would. Four cameras were installed inside the car to monitor the interactions of the drivers. Participants spent 1% of their driving time engaging with the navigation system and 4% of their driving time dealing with their mobile phone, excluding mobile phone talks, according to the findings. In the case of the mobile phone, 48 percent of engagements took more than 15 seconds, while in the case of the navigation system, it was 40 percent. The author came to the conclusion that a significant portion of driving time was spent on secondary activities, which might jeopardize safe driving.

Mora et al. (2012) investigated the effects of manually entering navigator destinations while driving in a simulator. 43 volunteers used the driving simulator SIMUVEG while entering directions into a navigator in order to evaluate the effects on driving performance. The capacity of drivers to maintain longitudinal and lateral vehicle control, as well as awareness of the road scene, was assessed. The results revealed a considerable loss of lateral and longitudinal control, as well as awareness of the visual surroundings, demonstrating the dangers of using electronic devices while driving.

The size and brightness of the GPS display can impact the duration and frequency of a driver's glances, which can lead to driver distraction. Yared et al. (2020) investigated the impact of the GPS's display size and lighting level on the performance and safety of young drivers on routes in urban and rural locations in a simulated driving experiment that required the usage of a GPS. According to the findings, driving in an urban environment with a smaller GPS display causes more navigational mistakes than driving with a large one. Furthermore, while using a GPS system to navigate, young experienced drivers are safer than inexperienced drivers.

Bicyclists' behavior while using portable electronic devices has been evaluated in three studies. Goldenbeld et al. (2012) showed that adolescent bikers who use portable electronic devices while riding are more likely to be involved in a bicycle accident than their peers who never use portable electronic devices while bicycling. De Waard et al. (2010), investigated bikers in the Dutch city of Groningen, which has a large student population, and discovered that using mobile phones had a detrimental influence on riding performance, especially when texting was included. The effects of listening to music on riding behavior were assessed in a similar research about distracted cycling conducted by de Waard et al. (2011). Twenty-five people rode their bikes around a track while listening to music through two normal earphones, one earbud, and two in-earbuds. The experiment also featured high-tempo music and high levels of loudness, as well as two mobile phone situations, one in which participants used the phone with their hands and one in which they did not. The authors came to the conclusion that listening to music impairs auditory perception, especially when in-earbuds are employed.

Terzano et al. (2013) investigated riding while conducting secondary tasks in the city of Hague, Netherlands, with an emphasis on using mobile phones, listening to personal audio devices, and chatting with fellow riders. Of the 1360 bicyclists, 47 (3.5%) were using a cell phone, 124 (9.1%) were listening to music on an iPod or other personal music device with headphones, 190 (14%) were engaging in conversation with another bicyclist, seven (0.5%) were smoking, and ten (0.7%) were doing something else not listed on the coding sheet. The completion of a secondary job, which might be a possible distraction, did make a difference in whether the biker acted safely or recklessly. 205 persons (20.8 %) of the 984 bikers who were not doing a secondary activity participated in risky behavior. In a study of 376 cyclists executing a secondary activity, 184 persons (48.9%) participated in risky conduct, with a range of 43–51 percent depending on the task.

The objective of Wolfe et al. (2016) study was to watch bikers in a big metropolitan region in the United States and collect data on distracted riding behaviours that are typical in high bicycle traffic junctions throughout Boston. In this investigation, a total of 1,974 bikers were observed. A total of 615 (31.2%) of the 1,974 were distracted. Auditory distractions were the most prevalent in this investigation,

followed by visual/tactile distractions. During the noon commute, the largest percentage of inattentive bikers (40.7%) was recorded (between 13:30 and 15:00). The analyses showed that distracted riding is a common safety risk in Boston, with nearly a third of all bikers engaging in such conduct. All available research done in the last years concerning driver distraction is limited. So is about distraction of cyclists especially on studies conducted under naturalistic driving conditions. In order to bridge these gaps, the current research makes an attempt to approach driver distraction of cyclists by conducting an experiment under real riding conditions while using a navigator.

3. Methods and Data

3.1 Description of experiment

To approach the phenomenon of driver distraction, a survey was conducted on fifteen bike riders. They were asked to ride a bicycle on a predetermined route within the city while using Eye Tracking Glasses, a device made by SMI. The experiment took place in May 2021 in Volos, Greece. Each of the participating riders followed the same procedure. Wearing eye tracking glasses and receiving instructions from a smartphone navigation application, reached the finish line from start to finish. The drivers did not know the route in advance, so that their reaction times correspond to the real ones.

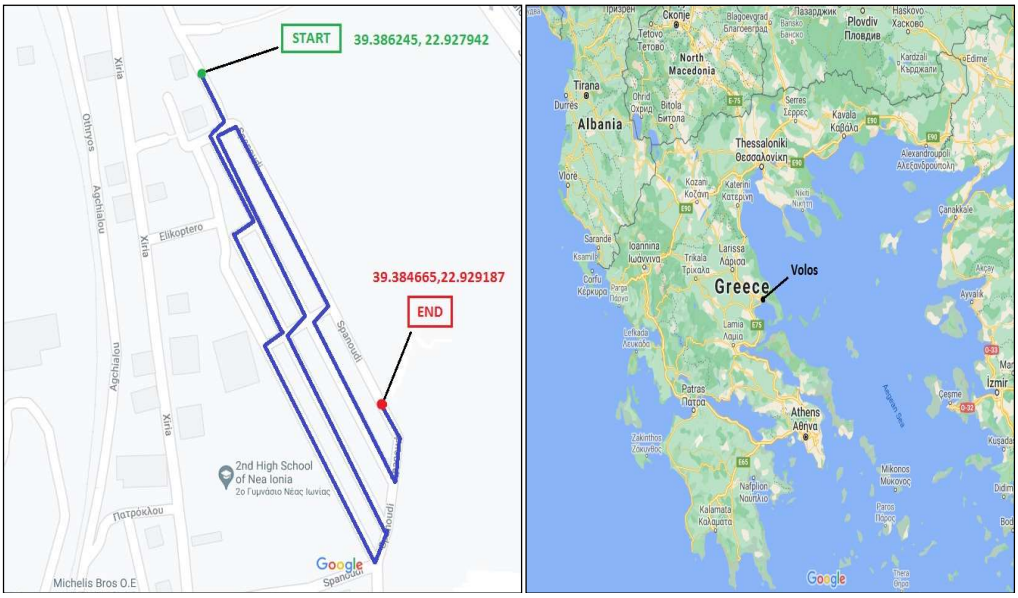
3.2 Participants

As mentioned above, the participating riders were fifteen in number. A prerequisite for their participation was the knowledge of cycling. Selection of the volunteering riders was made both by the friendly and the family environment. Each of them was asked to fill in a questionnaire after the end of the route, which concerned demographic data as well as data about the use of bicycle and navigator.

3.3 Route planning

To conduct the research, riders were asked to follow a specific route. This route, with a total length of 900 meters, is located in a parking lot on Spanoudi Street, near the Panthessaliko Stadium of Volos as seen on Figure 1. A major factor in the area selection process was the safety of the participants. This particular route was suitable due to reduced traffic load compared to others.

Figure 1: Study area route



3.4 Equipment

3.4.1 Bicycle

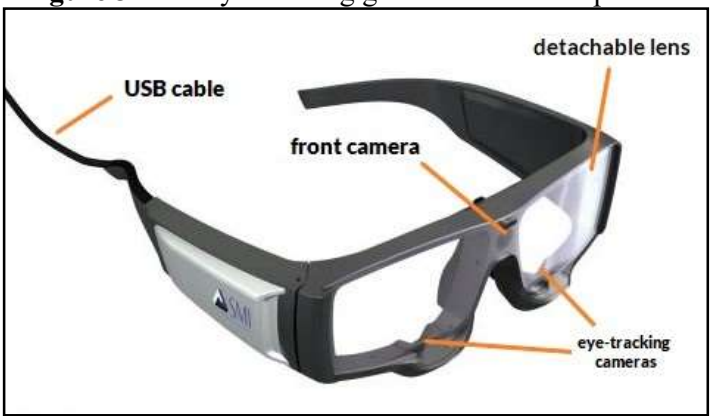
For the needs of the experimental study, a bicycle was used which was the same for all participants (Figure 2). This bike, blue colored, which belongs to the trekking category, is made by Ideal and has 28-inch wheels. Also, the model's name is Nergetic and is a 27-speed bike.

Figure 2: Bicycle used in the study

3.4.2 Eye tracking glasses

SensoMotoric Instruments' eye tracking glasses were used by the riders participating in the study (Figure 3). This device is a pair of glasses which has a camera on the front, two small cameras on the bottom to detect the movement of each eye and a microphone. The glasses are connected via a USB cable to a laptop in order to store the recording data. The connected laptop was carried by the participants in a backpack throughout the ride. In addition, for optimal integration of the system in both the environment and the driver's face, the system includes the ability to change the lens as well as special accessories to adapt to the nose area, so that the eye cameras are raised and the eyes are centered or the opposite.

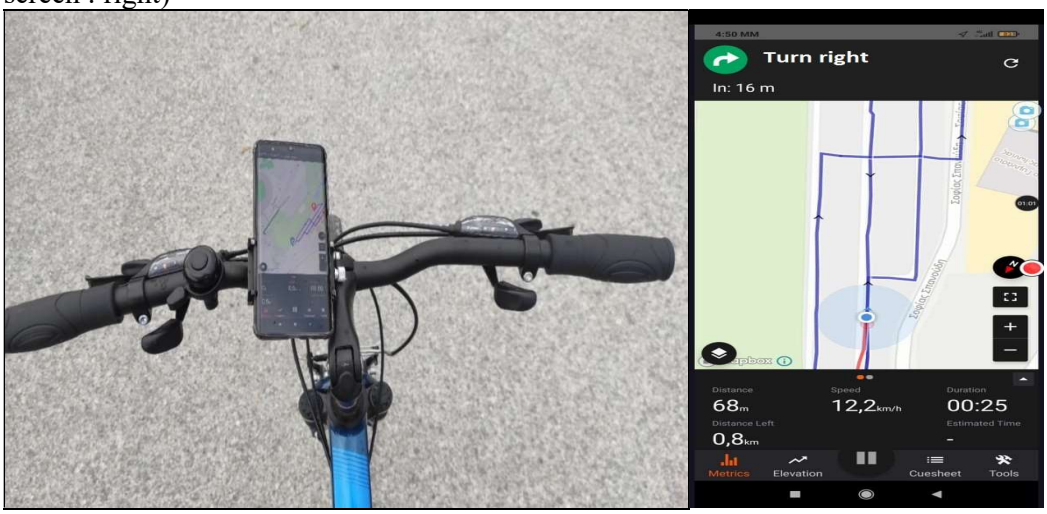
Figure 3: SMI eye tracking glasses and its components



3.4.3 Navigation

Participating riders were asked to follow the instructions given to them by a smartphone navigation application, which was located on the handlebar of the bicycle (Figure 4: left). The instructions given to the drivers were both visual (Figure 4: right) and acoustic.

Figure 4: Navigation on smartphone attached to bike's handlebar (Rider's view: left, Smartphone's screen : right)



The smartphone used was a Xiaomi Mi Note 10 Lite model which has a 6.47-inch screen. RidewithGPS application was used for navigation. Using the route planner feature available on the application, the predefined route was plotted and then the navigation cues were placed manually as shown (Figure 5). After this step, a message was composed for each cue (Table 1).

Figure 5: Route planning and positioning of cues

Table 1: Navigation commands

Cue No.	Message	Route distance (m)
1	Turn right, then turn left	23
2	Turn left	40
3	Turn right	91
4	Continue straight ahead, turn right at the intersection	142
5	Turn right, then turn left	173
6	Go straight and at the end of the road sharp turn left	254
7	Turn left	317
8	Then turn left again	333
9	Go straight and turn right at the intersection	430
10	Turn right	460
11	Then turn left	471
12	Continue straight ahead	533
13	At the end of the road take a sharp right turn	543
14	Turn right and then continue your right	595
15	Continue straight ahead, turn right at the intersection	693
16	Turn right, then turn left	733
17	At the end of the road take a sharp left turn	813
18	Turn left	851
19	End of route	900

3.4.3.1 Navigation problems

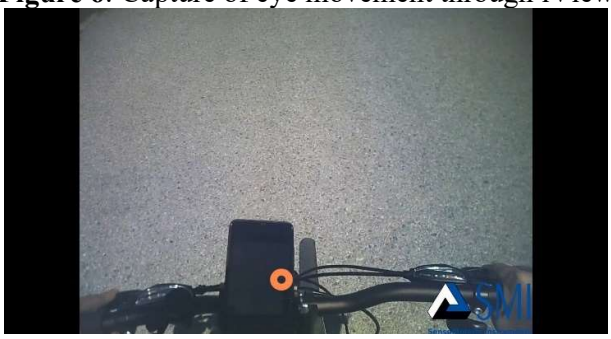
Due to the maps used by ridewithGPS application and the accuracy of device's GPS, navigation instructions number 8 and 13 were not activated during the navigation process of the participants,

without having a direct impact on the successful execution by each rider. For this reason, the distraction times in the diagrams that follow in next chapter, for those instructions, will be zero.

3.5 Data collection

iView ETG program was used to record the data on a laptop. Specifically, the recording of eye movement is achieved (Figure 6) through the device's cameras (eye-tracking glasses).

Figure 6: Capture of eye movement through iView



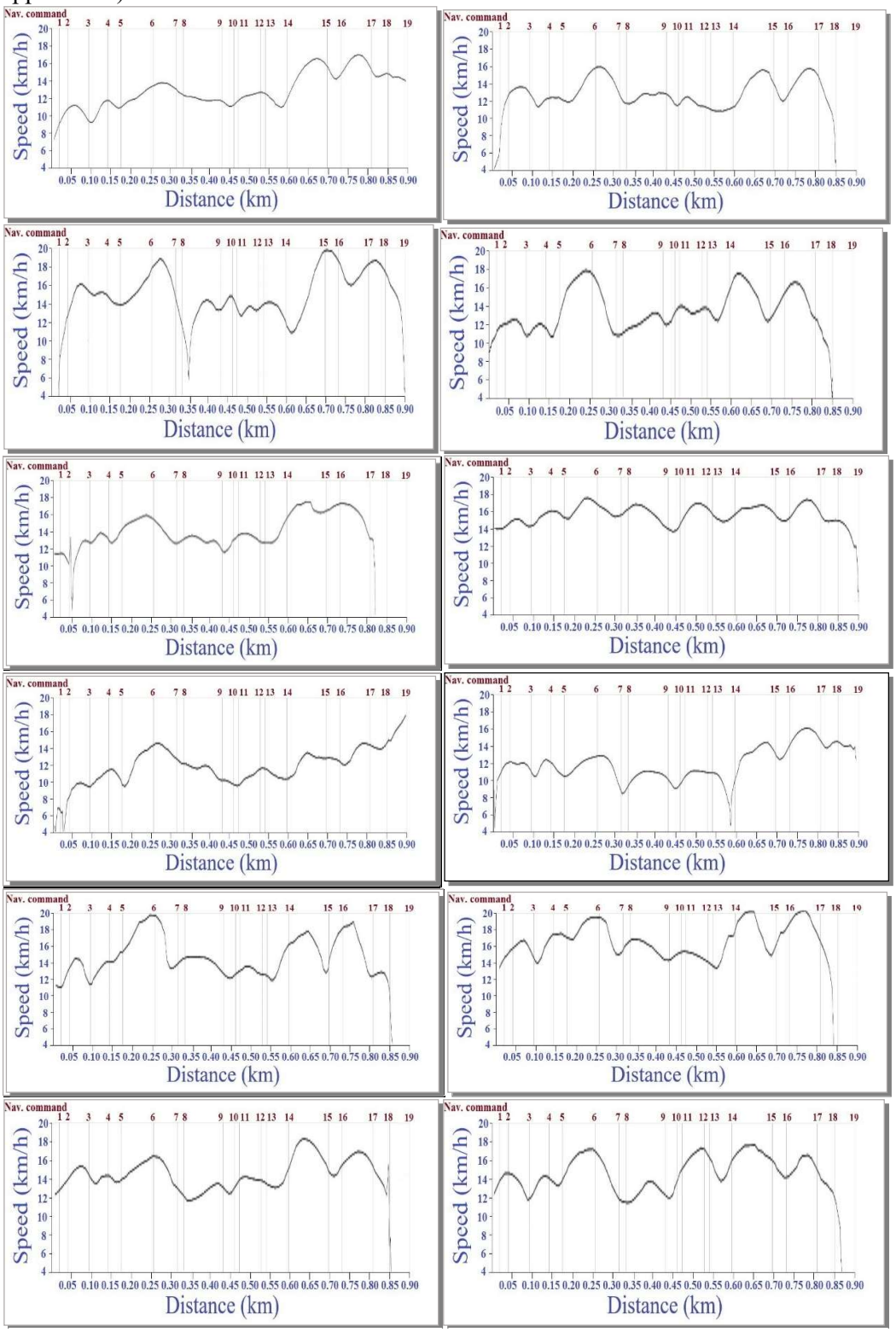
Prior to the start of the recording for each ride, a device adjustment process was required. This procedure aims at adjusting the front camera of the device as well as the eye cameras, so that the indications are correct and accurate. This was achieved by focusing the drivers' gaze on three specific points, where the user-driver looks at a fixed point and the program operator confirms it by clicking on that point (Figure 7). By the end of the adjustment process, the system was ready for recording.

Figure 7: Device adjustment process for each rider

4. Results

The data obtained from the voluntary participation of the riders were collected and analyzed after the end of the experiment. Figure 8 is related to speed in relation to the traveled distance for each participant while figure 9 shows speed in relation to the traveled distance for all participants. Figure 10 is showing distraction time in relation to traveled distance (of navigation commands) while figure 11 shows average distraction time of all riders. Figures 12 and 13 exhibit distraction time of riders (in each navigation command) depending on the use of bike and the experience in using navigator.

Figure 8: Speed vs traveled distance for each ride (Vertical lines stand for navigation commands' appearance)



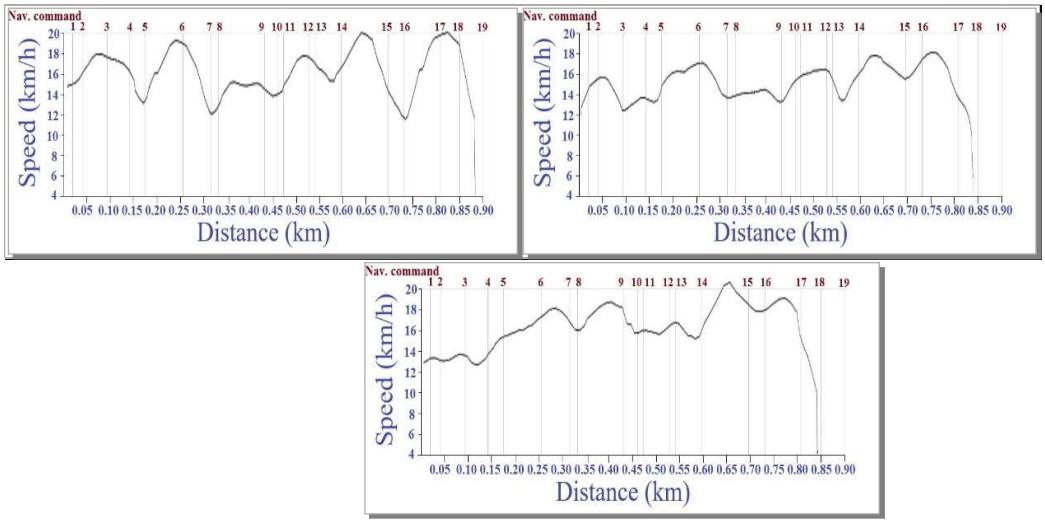


Figure 9: Speed vs traveled distance for all rides

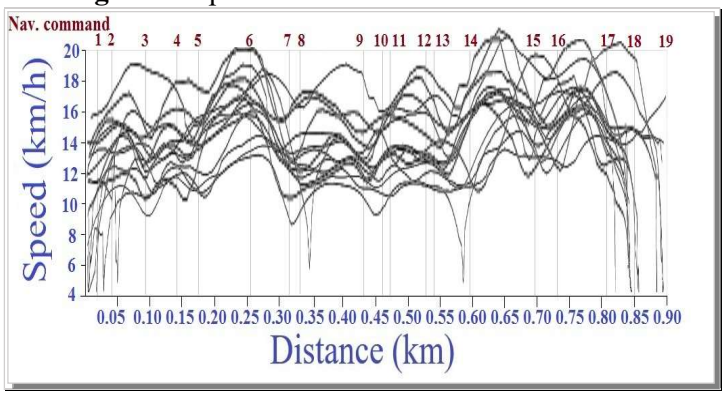


Figure 10: Distraction time vs distance (Navigation commands) for each ride

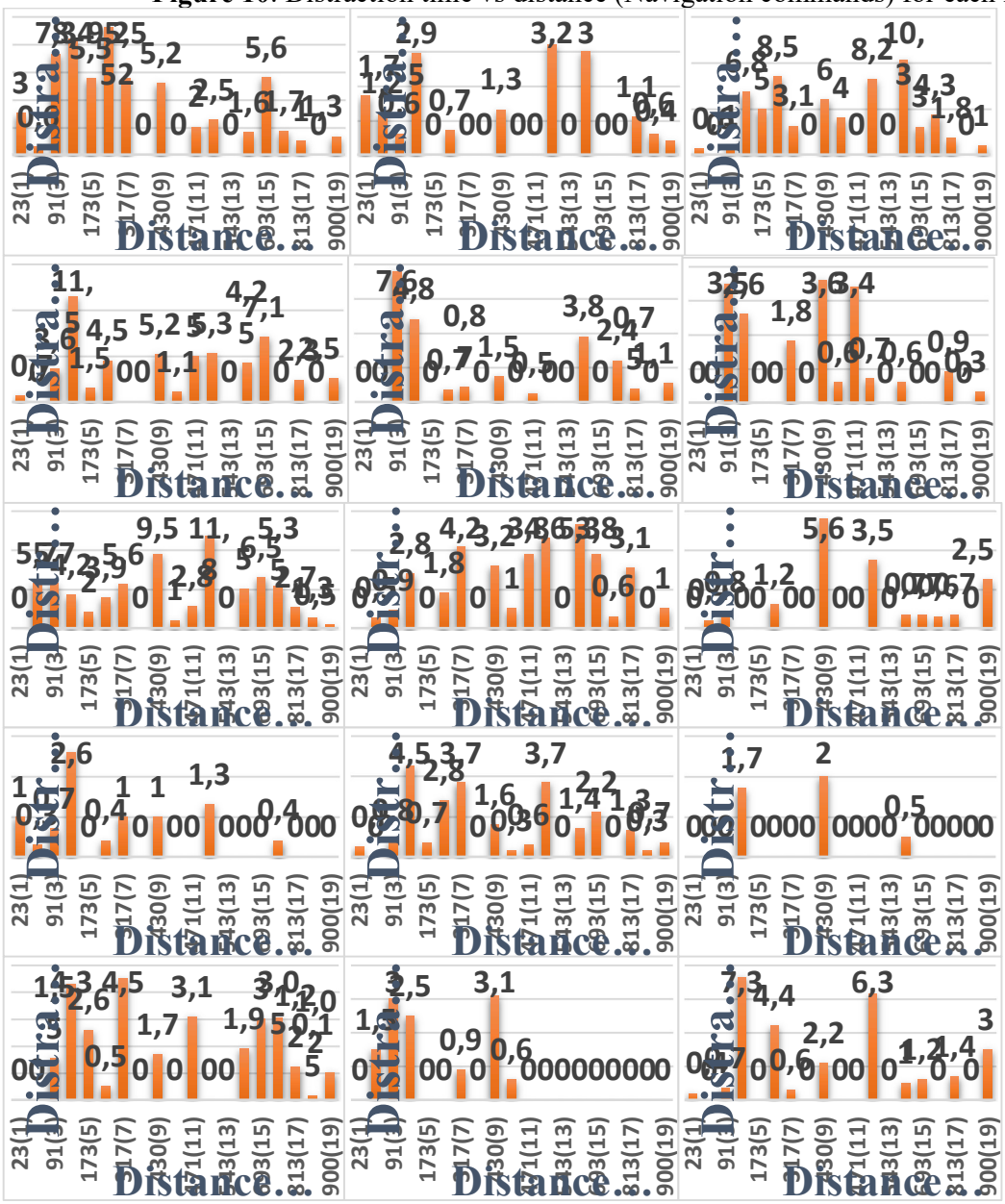


Figure 11: Average distraction time vs distance (Navigation commands)

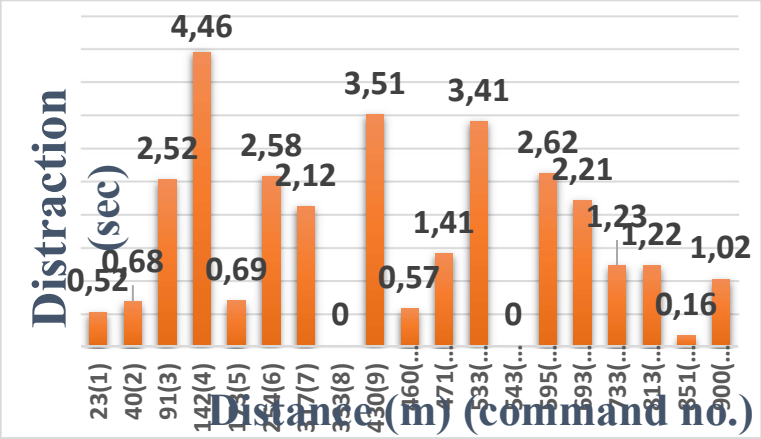


Figure 12: Average distraction time vs distance (Navigation commands) for bike users (left) and non-users (right)

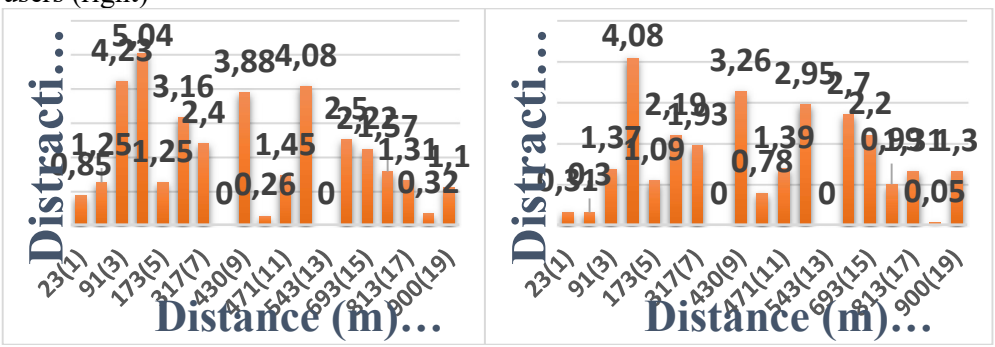
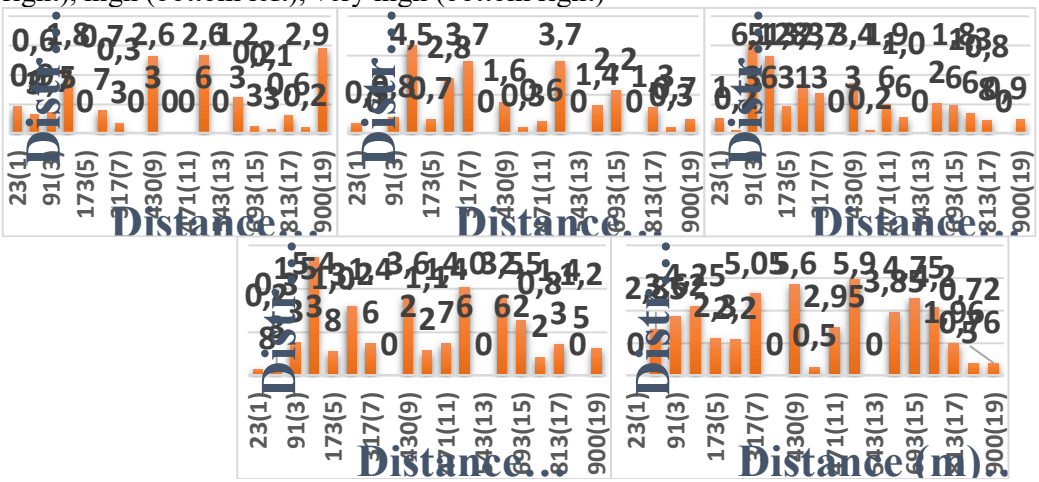


Figure 13: Average distraction time vs distance (Navigation commands) and navigator using experience. Very low navigator-using experienced riders (top left), low (top center), moderate (top right), high (bottom left), very high (bottom right)



5. Conclusions

Although there is a significant reduction of road deaths in the last years, Greece still remains high on the list, thus deeming the urgent need to take measures and actions in the right direction. The data of road accidents worldwide as well as the outcome of various studies, highlight the seriousness and the

importance of driver's distraction. In Greece, however, the only data available are the accident statistics as no research has been completed on the subject.

In this research, an approach in cyclists' safety and specifically in the distraction of cyclists was made by conducting field tests. The results of the experiment performed, show us that the phenomenon of bicycle riders' distraction is real and plays a major role in causing road accidents in urban environments. The riders glanced, several times and for many seconds, away from the driving task. Participants who are also bicycle users, moved their eyes away from driving for a longer period compared to those who do not use a bicycle. In contrast, riders who were less familiar with navigating were observed to have shorter distraction times. It is also worth mentioning that riders felt that their attention was not distracted from the driving task during their rides.

The goal of this study was to quantify distracted riding behaviors and provide a baseline assessment to assist evidence-based public education and awareness campaigns aimed at reducing distracted bicycling behaviors. In addition, we expect that this study will give information regarding the prevalence of this new bicycle safety concern within the biking community, to injury prevention specialists, local law enforcement, and state and federal highway safety agencies.

References

Christoph, M., van Nes, N., & Knapper, A. (2013). Naturalistic Driving Observations of Manual and Visual–Manual Interactions with Navigation Systems and Mobile Phones While Driving.

Cooper JM, Vladisavljevic I, Medeiros-Ward N, Martin PT, Strayer DL. (2009). An investigation of driver distraction near the tipping point of traffic flow stability. Human Factors 51(2):261-268

De Waard, D., Schepers, P., Ormel, W., & Brookhuis, K. (2010). Mobile phone use while cycling: Incidence and effects on behaviour and safety.

De Waard, D., Edlinger, K., & Brookhuis, K. (2011). Effects of listening to music, and of using a handheld and handsfree telephone on cycling behaviour

Goldenbeld, C., Houtenbos, M., Ehlers, E., & De Waard, D. (2012). The use and risk of portable electronic devices while cycling among different age groups. Journal of Safety Research, 43(1), 1–8.

Hedlund, J., Simpson, H., Mayhew, D. (2005). International Conference on Distract-ing Driving: Summary of Proceedings and Recommendations (2–5 October).

Hoel, J., Jaffard, M., Van Elslande, P. (2010). Attentional competition between tasksand its implications.

Knapper, A., Christoph, M., Hagenzieker, M., & Brookhuis, K. (2015). Comparing driving simulator to the real road regarding distracted driving speed. European Journal of Transport and Infrastructure Research, 15(2).

Lee, J.D., Young, K.L., Regan, M.A. (2008). Defining driver distraction.

Lemonakis P., Koroni M., Misokefalou E., Eliou N. (2021) Recording and Evaluation of Motorcyclists' Distraction of Attention in Urban Areas. In: Nathanail E.G., Adamos G., Karakikes I. (eds) Advances in Mobility-as-a-Service Systems. CSUM 2020. Advances in Intelligent Systems and Computing, vol 1278. Springer, Cham.

Lemonakis P., Botzoris G., Galanis A., and Eliou N. (2020) A GPS-based Methodology for Analyzing Bicyclist's Behavior in Different Road Environment. Proceedings of the International Conference on Sustainable Expert Systems (ICSES 2020). Lecture Notes in Networks and Systems, Volume 176.

Lemonakis P., Misokefalou E., Koroni M., Eliou N. (2020) Recording and evaluating motorcyclists' gaze behaviour in rural roads. 13th International Motorcycle Conference, 05/10/2020, Cologne, Germany.

Manser, M. P., Ward, N. J., Kuge, N., Boer, E. R. (2004). Influence of a driver support system on situation awareness in information processing in response to lead vehicle braking.

Montoro L, Alonso F, Esteban C, Toledo F. (2000). Road safety manual: the human factor. Barcelona: Ariel.

Misokefalou E., Koroni M., Lemonakis P., Eliou N., (2021), Συγκριτική αξιολόγηση απόσπασης προσοχής οδηγών μοτοσυκλέτας σε αστικό και υπεραστικό περιβάλλον, 10th International Congress on Transportation Research, 1-3 September 2021, Rhodes

Pettitt, M., Burnett, G., Stevens, A. (2005). Defining driver distraction

Porter BE (ed.) (2011). Handbook of traffic psychology. New York: Elsevier.

Ranney, T., Garrott, R., Goodman, M. (2000). NHTSA driver distraction research: Past, present, and future', USDOT, National Highway Traffic Safety Administration

Regan, M., Hallett, C., Gordon, C. (2011). Driver distraction and driver inattention: Definition, relationship and taxonomy

Sheridan, T. B. (2004). 'Driver Distraction From a Control Theory Perspective.', Human Factors

Smiley, A. (2005). What is Distraction? International Conference on Distracted Driving. Human Factors North Inc.

Streff, F., Spradlin, H. (2000). Driver distraction, aggression, and fatigue: a synthesis of the literature and guidelines for Michigan Planning. The University of Michigan Transportation Research Institute, United States.

Terzano, K. (2013). Bicycling safety and distracted behavior in The Hague, the Netherlands.

Treat, J.R. (1980). A study of precrash factors involved in traffic accidents. The HSRI Review

Valero Mora, P. M., Ballestar Tarín, M. L., Tontsch, A., Pareja Montoro, I., & Sánchez García, M. (2012). Effects of manually entering navigator destinations while driving in a simulator.

Yared, T., Patterson, P., & All, E. S. A. (2020). Are safety and performance affected by navigation system display size, environmental illumination, and gender when driving in both urban and rural areas?

New Trans-Arctic shipping routes: Opportunities and challenges for shipping and maritime transport

Joniada Tahiraj & Antonios Skouloudis
Dep. of Environment, University of the Aegean
j.tahirajalb@gmail.com, skouloudis@aegean.gr

Abstract
The impact of climate change in the Arctic Ocean has opened new possibilities for shipping companies. The two main routes in the Arctic Ocean that are used by ships, the Northeast Passage (NEP) and the Northwest Passage (NWP) present both opportunities and challenges and it is estimated that by mid-century new trans-Arctic shipping routes will be navigable. Reduction in travel time and fuel demand, less emissions, safer transit are key advantages these routes provide. However, commercial viability for the utilization of these seaways requires an interdisciplinary approach taking into consideration market needs, costs, revenue, cash flow parameters along with the intrinsic characteristics of the Arctic Region, i.e., the extreme weather conditions and the progressively stricter environmental regulations applied in maritime industry. In this study we examine how shipping companies can be affected by Polar Code Environmental Requirements and the imposition of UN IMO ban approval on the use of heavy fuel oil and its carriage for use by ships in their perspectives to utilize the polar seaways. To achieve this, a questionnaire was developed with categorized criteria of the Polar Code, potential incentives, and practices for which companies were asked to provide their viewpoints and perceptions. Our findings indicate that companies ranks environmental requirements as one of the most costly demands, recognizing the stricter environmental regulations applied onward and adapt to these policies to maintain their competitiveness and improve environmental performance of their vessels. However, their decision to involve in transit shipping in Arctic Waters depends on numerous factors and is associated more with business strategy, which does not include this market, rather than the cost that environmental regulations generate. As the study's respondents primarily pertain to shipping companies with 1-10 bulk carriers fleet size based in Greece, further research could draw from a larger and more diverse sample of shipping companies that already operate through the Arctic Waters routes.

Keywords: Arctic waters, shipping/maritime sector, climate change.

JEL Codes: Q54; Q01; Q56; M14.

Environmental Literacy and Climate Change Perceptions of Primary School Teachers

Chrysovalantis Kalessopoulos[1], Anastasia Gkargkavouzi[2] & Steriani Matsiori[1]

[1] *Interdepartmental Postgraduate Studies Program Education for Sustainability and the Environment, Department of Ichthyology and Aquatic Environment, School of Agricultural Sciences & Department of Special Education, School of Humanities, University of Thessaly*

[2] *Greek Ministry of Education and Religious Affairs, Directorate of Primary Education of Zakynthos*

ckalessop@uth.gr, agkargkavouzi@uth.gr, steriani@uth.gr

Abstract

Environmental Education Programs aim to promote ecological citizenship based on environmentally literate students. In this sense, teachers must be sufficiently qualified to support their students towards a sustainable lifestyle. The main goal of this study is to explore the environmental literacy levels of primary school teachers and their perceptions of climate change: A total of 200 teachers completed an online questionnaire. Environmental Literacy was measured via scales of ecological knowledge, attitudes, values, ecological behavior, and skills. Based on bivariate and multivariate data analysis, the results showed a moderate level of environmental knowledge, positive attitudes, and enhanced values. On the contrary, levels of ecological behavior and skills were relatively low. These findings enable the refinement of the curricula of the Pedagogical Departments of Universities that seek to promote sustainability and develop environmentally literate citizens.

Keywords: Environmental Literacy, climate change, ecological citizenship, sustainability, primary school teachers.

JEL Codes: I20; C31; Q54.

Energy literacy assessment of Greek secondary students

Konstantinos Kougias [1], Eleni Sardianou[1], Anna Saiti[2] & Konstantinos Tsagarakis[3]
[1]*Department of Economics and Sustainable Development, Harokopio University, Athens*
[2] *Department of Early Childhood Care and Education, University of West Attica, Athens*
[3]*School of Production Engineering and Management, Technical University of Crete, Chania*
kkougias@hua.gr, esardianou@hua.gr, asaiti@uniwa.gr, ktsagarakis@pem.tuc.gr

Abstract
Environmental awareness and energy literacy is an issue that has been emerged in the last decade, attracting increasing attention mainly from the international education systems. Knowledge of energy, its use and students' attitudes towards its consumption are key points for the sustainability of the environment and the economy in the future. The purpose of this paper is to investigate, through empirical analysis, the level of energy literacy of junior high school students in Greece. The analysis is based on 1200 questionnaires completed by junior high school students. The preliminary results indicated that Greek students, to a great extent, have poor basic knowledge about energy, which leads them to its unsustainable use. The outcomes of the study can be a power tool for educational planners to create a curricula oriented towards sustainable energy use.

Keywords: Sustainability, energy literacy, secondary students, environment, energy education.

JEL Codes: I2; Q01; Q20; O30; O40.

Environmental education and sustainability

Ioanna Grigoriadou, Ourania Gkouna & Georgios Tsekouropoulos
International Hellenic University, School of Economy & Administration, Department of Administration of Organizations, Marketing and Tourism, Sindos Thessaloniki 574 00
ioanna.grig@outlook.com, ouraniagouna@gmail.com, geotsek@bua.teithe.gr

Abstract
Environmental education, with a view to promoting sustainable development and the useful technology that accompanies it, contributes to a more constructive approach to knowledge and the development of systemic thinking. In this conceptual framework, it is important to cultivate individual skills which enable us to re-shape the future in terms of environmental and social sustainability in order to approach, process and arrange day-to-day environmental challenges. The ultimate goal is the understanding of this complex and multi-leveled issue, but also the utilization and application of this knowledge through educational action. In particular, the implementation of these training processes is of major importance as a means of achieving sustainable development. In this context, the current study investigates the effectiveness of environmental education as unessential tool in educating the new generation on preventing and solving environmental problems. The research concludes that environmental education can not only be applied to schools and higher and technical education, but also serve as vocational training to ensure better understanding of the relationship between man and the natural environment, through the tools of natural and digital learning that are in line with the reduction of our environmental footprint and the promotion of sustainability.

Keywords: Environmental Education, Sustainability, Education, environmental issues

JEL Codes: O21; Q28; Q42; Q48.

Effective educational units: Perceptions & Attitudes of the teachers of public primary schools of the Prefecture of Thessaloniki

Msc Eleni Vlachoudi[1], Dr. Georgios Tsekouropoulos[2], Dr. Nikolaos Katsonis[3]
[1] Teacher, Primary Education of Western Thessaloniki,
[2]Assistant Professor, International Hellenic University, Department of Organization Management, Marketing & Tourism,
[3]Director of Public Experimental I.E.K. Patras
elenaki282008@hotmail.com, geotsek@bua.teithe.gr, nikoskatsonis@gmail.com

Abstract
In a society that is constantly changing and evolving, the school is called to play a very important role, which should be both quality and effective. The purpose of this study is to highlight the factors that can affect the effectiveness of a school unit and to investigate the relationship between these factors. According to the results of the study, teachers believe that factors related to both pedagogical and learning function as well as the administrative function of education, contribute to the increase of the efficiency of the school units, while it is worth noting that there were differences in the answers of the participants in terms of position of responsibility, of years of service and of their educational level. In addition, the professional development of the teaching staff, which is achieved through their participation in training seminars, seems to have a positive effect on the effectiveness of a school structure. In conclusion, it is worth noting that there was a strong positive linear relationship between the factors that can increase school effectiveness.

Keywords: Effectiveness, attitudes and perceptions of teachers, primary education, organizational culture, behavior

JEL Classification: I20

1. Introduction

The role that teachers are called upon to play in modern times is particularly demanding as their goal is to introduce the student community to a new reality, adopting the goals of sustainable development that have been accepted by world leaders and that will lead to the creation of a healthy planet. In this context, one of the goals is to provide equal, quality and lifelong learning for all humanity.

The improvement of the provided educational project and consequently the increase of the efficiency of the educational units can be achieved by the human resources that constitute the main resource of the school structures. Teachers, through the performance of their teaching work, can contribute to the provision of quality education to the entire student population of a school. However, in order to be able to fulfill this very demanding role, they should participate in trainings, which will ensure their professional development at the same time (Doukas et al., 2007).

2. Literature Review

The human resources of a school structure, in order to achieve the intended teaching objectives, are called to choose all the means, methods and teaching activities that will be used for the organization and implementation of educational planning (Katsarou & Dedouli, 2008). As the teacher contributes through his teaching to the provision of quality educational results (Xochellis, 2003), he must cope with his multidimensional role through his personal improvement (Sofou & Dieronitou, 2015). Therefore, it is considered necessary and expedient to participate in training activities, through which both lifelong learning and the improvement of the quality and efficiency of the educational unit in which they work will be achieved (Douka et al., 2007).

According to Papanaum (2007) the training of a teacher is achieved through their involvement in learning activities and is related to the enhancement of pre-existing knowledge and skills with new academic or practical content that ultimately aims at professional development. In addition, a teacher must over time enrich and enhance the basic knowledge he has acquired in order to carry out innovative programs related to the educational policy of the state (Sofou & Dieronitou, 2015).

It is worth noting that the professional development of the teaching staff of a school unit is a perpetual process, implemented through a number of actions, with the ultimate goal of specialization in specific areas and training in the management of various situations within the school classroom (Sofou & Dieronitou, 2015). In order for teachers' professional development to bring about optimal results, new experiences must be linked to existing knowledge (Ganser, 2000).

It is worth mentioning that there are some conditions that must be met in order for the professional development of teachers to be an effective process. More specifically, it is advisable to have the necessary support and facilitation from the management of the school unit and in addition to have relevance to the subject (Dudzinski et al., 2000; Ganser, 2000). It should also be noted that professional development is a collaborative process as it depends on and is determined by the teacher's interaction with all stakeholders at the stage of final evaluation of the educational process (Clement & Vanderberghe, 2000).

At this point it should be mentioned that the participation of the teaching staff of the school in professional learning communities, the objectives of which are in line with those of the school unit, can contribute to the professional development of teachers (Balasi, 2020). More specifically, the participation of teachers in professional learning communities contributes to the development of the school into a learning organization within which the development of the individual who participates in it takes place (Wald & Castleberry, 2000).

3. Methods and Data

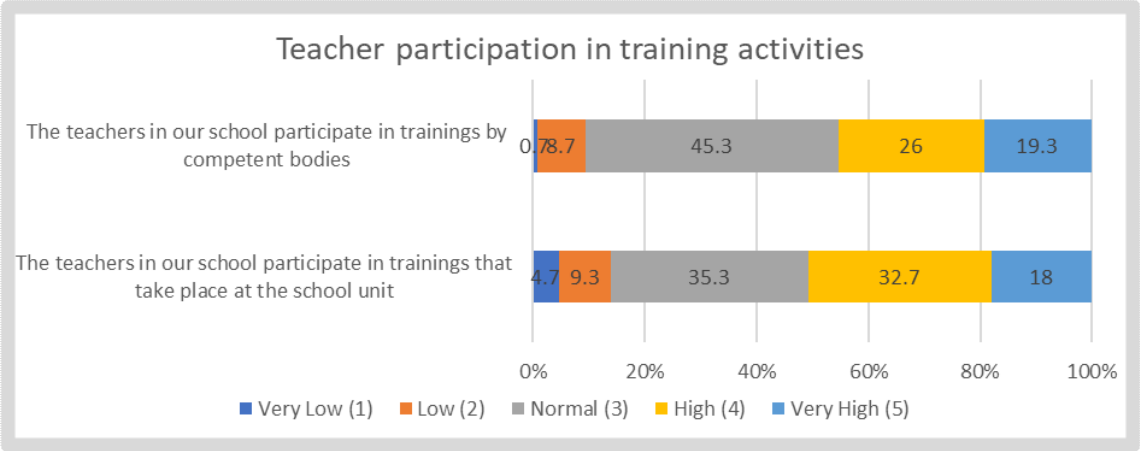
This article examines whether the professional development of teachers can contribute to the provision of quality, lifelong learning. The research was aimed at the population of Primary education teachers

working in schools of the Prefecture of Thessaloniki. More specifically, 70 teachers from educational units in Eastern and 80 from schools in Western Thessaloniki participated in the research.
The method of Sampling with probabilities was used while the composition of the sample was done in layers based first on the profession of the respondents and then based on their place of permanent residence. Participants were asked to respond to an online questionnaire written through Google Forms. As the investigation was conducted in the midst of the coronavirus pandemic it was the most appropriate way of collecting data due to the restrictive measures taken by the government in the context of its containment. 150 questionnaires were collected, the statistical analysis of which was performed with the SPSS program.

4. Empirical Results

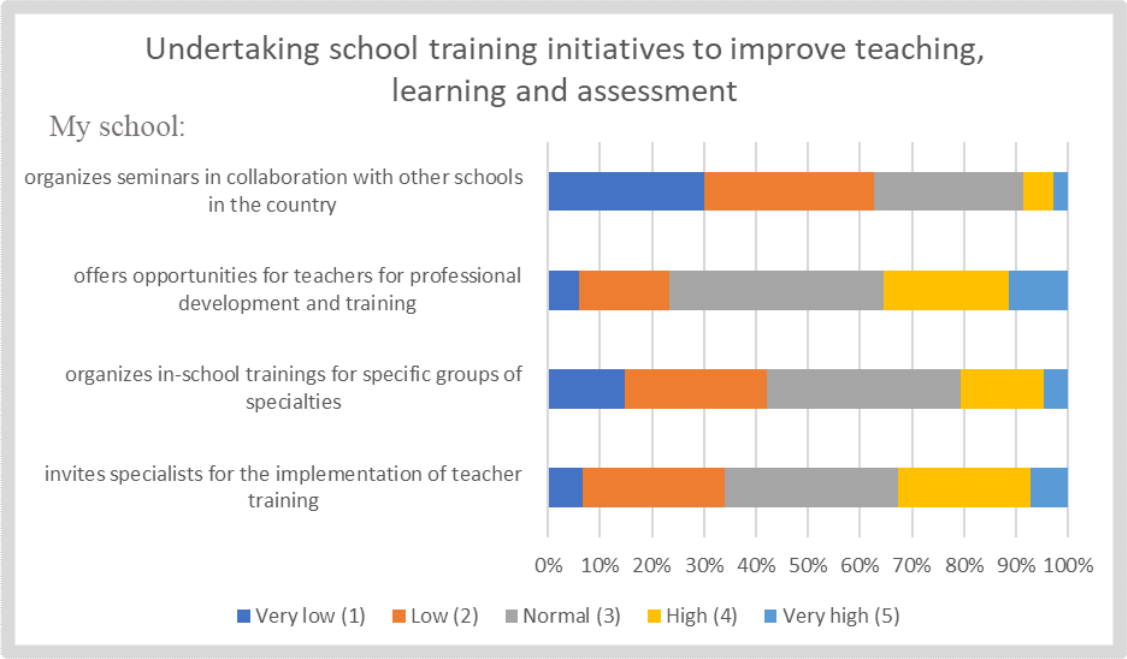
Moving on to the results of the research, we should mention that regarding the participation of teachers in training activities, from the results represented in Figure 1, it is concluded that the respondents participate to a large extent ("High") in in-school training (Average value = 4), while to a moderate degree ("Normal") they participate in trainings by competent bodies (Average price = 3).

Figure 1: Distribution of sample answers to questions related to teachers' participation in training activities and appropriate descriptive measures



The opinion of the teachers who participated in the research is in line with the findings of Doukas and his colleagues (2007), who argue that the involvement of teaching staff in training programs is very important for improving the quality and effectiveness of a school unit.
Next, regarding the school's training initiatives to improve teaching, learning and assessment, it appears that their school to a moderate degree ("Normal"), "invites teachers to implement teacher training", "organizes in-school training" training for specific groups of specialties "and" offers opportunities for teachers for professional development and training "(Medium price = 3), while to a small extent ("Low")," organizes seminars with other schools in the country "(Medium price = 2) (Figure 2).

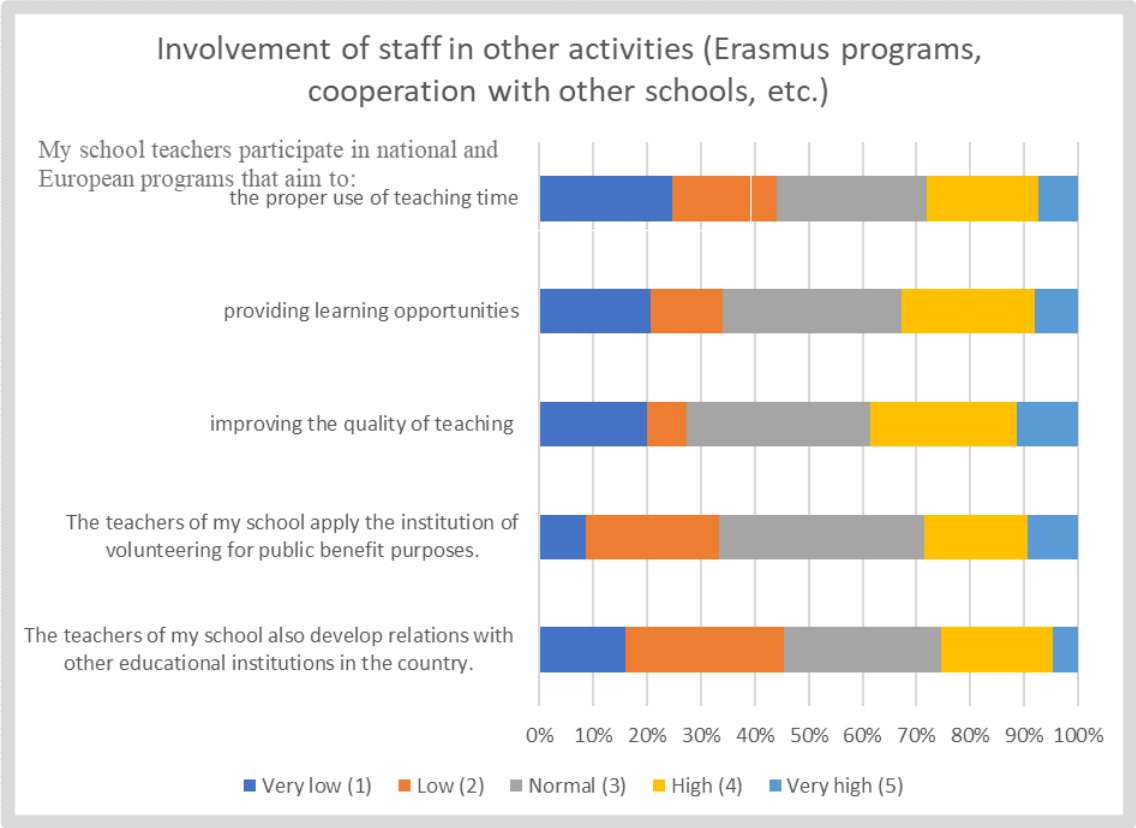
Figure 2: Distribution of sample answers to questions related to school training initiatives to improve teaching, learning and assessment and appropriate descriptive measures.



These results contradict the findings of the research, according to which in order for the professional development of teachers to be effective, it should be supported by the school unit and related to educational activities (Dudzinski et al., 2000, Ganser, 2000). However, the role of principals is also important, who according to Reynolds and Teddlie (2000), should support the implementation of in-school training in order to empower teachers.

Regarding the participation of teaching staff in national and European programs with various objectives (Figure 3), this seems to be mediocre, which is not in line with the findings of the respective surveys, according to which the need to respond to innovative educational policies leads the modern teacher in his training in a variety of subjects (Douka et al., 2007), such as sustainability, digital literacy and acceptance of diversity. Finally, the cooperation of teachers with other schools in the country and the implementation of volunteering are implemented to a moderate degree, as stated by the respondents.

Figure 3: Distribution of sample answers to questions related to staff involvement in other actions and appropriate descriptive measures



5. Conclusions

In conclusion, we should emphasize that teachers consider their participation in training programs to be important for their personal development, however they themselves do not seem to seek to participate in national and European programs.

The present study could be the trigger for the implementation of a larger scale research. Furthermore, conducting the research with the participation of teachers of both primary and secondary education would enable researchers to compare the results and determine whether the views of teachers differ according to the educational level they serve.

Continuing the proposals, the participation in the research of teaching staff from private schools would help to carry out a comparative study between public and private schools, so as to enable a comparison of the results of different educational units.

An interesting suggestion is to add open-ended questions to the research questionnaire, in order to give the participants, the opportunity to express their personal views, without being limited to predefined answers.

In addition, research could be conducted on the topics in which teachers wish to be trained.

References

Balasi, A. (2020) *Primary schools as professional learning communities and the professional development of teachers.* Doctoral dissertation (online). Florina: University of Western

Macedonia. Available at: https://thesis.ekt.gr/thesisBookReader/id/47131?lang=el#page/1/mode/2up (23/7/21)

Clement, M., & Vanderberghe, R. (2000). "Teachers' professional development: a solitary or collegial (ad)venture?" *Teaching and Teacher Education*, 16, 81-101. https://doi.org/10.1016/S0742-051X(99)00051-7

Doukas, Ch., Vavouraki, A., Thomopoulou, M., Koutra, Ch., Smyrniotopoulou A. (2007) "The quality approach to training: Training for the professional development of teachers and the improvement of the school." *Inspection of educational issues*. vol. 13, pp. 113-123. http://www.pi-schools.gr/download/publications/epitheorisi/teyxos13/113-123.pdf (23/7/21)

Dudzinski, M., Roszmann-Millican, M. & Shank, K. (2000). "Continuing professional development for special educators: reforms and implications for university programs". *Teacher Education and Special Education*, 23 (2), 109-124. https://doi.org/10.1177/088840640002300205

Ganser, T. (2000). "An ambitious vision of professional development for teachers". *NASSP Bulletin*, 84, 69-74. https://doi.org/10.1177/019263650008461802

Katsarou, E. & Dedouli, M. (2008). *Training and Evaluation in the field of Education*. Athens: Ministry of Education and Religions – Pedagogical Institute. Retrieved on 20/3/2014 from: http://www.pischools.gr/programs/epim_stelexoi/epim_yliko/book5.pdf

Papanaum, Z. (2007). Autonomy of the school unit. In P. Xochellis (Ed.), *Dictionary of Pedagogy* (pp. 83-86). Thessaloniki: Kyriakidis Brothers.

Reynolds, D. & Teddlie, C. (2000). The processes of school effectiveness. In C. Teddlie & D. Reynolds (Eds.), The international handbook of school effectiveness research. 134–159. London: Falmer Press. Retrieved from: https://doi.org/10.4324/9780203454404 (2/6/21)

Sofou, E. & Dieronitou, Eir. (2015) "Training and professional development of teachers through the procedures and practices of school self-evaluation: A case study" *Educational cycle*. vol. 3 (issue 1), pp. 61-82 https://journal.educircle.gr/images/teuxos/2015/teuxos1/4.pdf (23/7/21)

Wald, P. J. & Castleberry, M. S. (2000). Educators as Learners: Creating a Professional Learning Community in Your School. USA: ASCD. Διαθέσιμο στο: https://files.eric.ed.gov/fulltext/ED439099.pdf (23/7/21)

Xochellis, P. (2003). *School Pedagogy*. Thessaloniki: Kyriakidis Bros.

Educate environmentally conscious teenagers through music and movement

Vasiliki Tsekouropoulou[1], Vasileios Kasmeris[2] & Eleni Tsompanaki[3]
[1] *Aristotle University of Thessaloniki, Conservatoire of the Municipality of Kalamaria*
[2] *International Hellenic University, Conservatoire of the Municipality of Kalamaria*
[3] *University of Thessaly, Department of Early Childhood Education,*
Model Dance School of the Municipality of Kalamaria
viky.tsekouropoulou@uom.edu.gr, aristotelis_papaioanpu@hotmail.com, tsompanakielen@gmail.com

Abstract
Nowadays environment has come under serious threat. It is urgent to embrace it more than ever. Education has always been the key to development, thus we educate teenagers on how to consider environmental issues. This paper focuses on the educational values of performing arts in order to familiarize high school students with the environment. Based on Fluxus movement and the Happenings, a contemporary music named *Romance* was composed for such a purpose by Tsekouropoulou and danced in open air by Tsompanaki. The videorecorded project was presented to students from music and dance conservatoires, so as to familiarize them with natural sounds and movement qualities and assist them to make their own music and dancing projects through team work.
Particularly, we believe that incorporating music and movement in nature into Schools' curriculum can be of great assistance for students to develop both environmental conscience and acquire artistic identity. The project can be applied to Greek Conservatoires-Dance Schools and High schools. Music and dance teachers encourage students to produce sounds by using natural elements - trees, rocks, pines- and to move freely outdoors by using movement qualities and gestures, to be inspired by nature and to express themselves and be artistically creative.

Keywords: Music, movement expression, artistry, teamwork.

JEL Codes: I20.

Economic valuation of «Prepaid Bag - Pay As You Throw (PAYT) System» and «Rewarding Recycling Program»: Case Study of the Municipality of Kozani

Theodoros Adamidis & Dionysis Latinopoulos
School of Spatial Planning and Development, Faculty of Engineering, Aristotle University of Thessaloniki, 54124, Thessaloniki, Greece
theoadam@plandevel.auth.gr, dlatinop@plandevel.auth.gr

Abstract
The aim of this study is to provide estimates, through a questionnaire survey, of: (a) the Willingness to Pay (WTP) for a «Prepaid Bag - Pay As You Throw (PAYT) System», as well as (b) the Willingness to Accept (WTA) for a «Rewarding Recycling Program» respectively. The main objective of this analysis was to measure the value that the citizens of the Municipality of Kozani attribute to improving the solid waste management system. We also tried to identify the socio - economic determinants influencing their WTP values.
A structured web-based questionnaire survey method was used as a research tool for data collection from respondents in order to estimate respondents' intention to participate in waste separation and recycling processes. The Contingent Valuation Method (CVM) was applied as the research method to elicit people's WTP and WTA for the two aforementioned solid waste management programs. The statistical analysis with regard to citizens' WTP values revealed the important role that education and environmental information can play in order to stimulate pre-environmental behavior with regard to individual waste reduction.
Considering the policy implication of our results, policy makers could use them in order to further evaluate the potential use of economic (market-based) instruments in order to improve the urban solid waste management in the Municipality of Kozani.

Keywords: Willingness to Pay (WTP); Willingness to Accept (WTA); Contingent Valuation Method (CVM); Prepaid Bag - Pay As You Throw (PAYT) System; Rewarding Recycling Program

JEL Classification: Q51; Q53; Q56; Q57.

1. Introduction

All over the world, waste generation rates are continuously rising. Solid waste disposal is mainly linked to urbanization, population growth and economic development (Alam and Ahmade, 2013; Rezaei et al., 2010). Specifically, solid waste management is becoming more complex in countries with increasing urbanization, where infrastructures and services (such as the collection of solid waste) are more critical (Medina, 2010).

In 2016 the world's cities generated 2.01 billion tons of solid waste. As countries are rapidly urbanizing and population is still growing, the annual waste generation is expected to increase to 3.40 billion tons in 2050 (Kaza et al., 2018). Therefore, solid waste management is expected to pose major public health and environmental threats in urban areas (Kassa and Teshome, 2016). Managing solid waste is thus becoming a major challenge of urban areas of all sizes, from mega-cities to small towns and large villages (Sankoh and Yan, 2013; Wilson and Velis, 2014). Efficient solid waste management (SWM) can therefore play a crucial role in order to improve the environmental quality through increased amenity values, non-use values and provision of source of livelihood (Behzar et al., 2011). In this context, all levels of spatial planning, from the smallest circular systems of neighborhood to the larger cities and municipalities, should take urban solid waste management into account, in order to balance the environmental protection with the associated social and economic needs/goals. For this reason, urban solid waste management must holistically address the high degree of urbanization and the low availability of potentially suitable sites for waste disposal. According to Karagiannidis et al. (2006) problems related to the lack of incentives for both concerned citizens and state agencies (waste collection charge, municipal taxes) may from a poorly designed system of waste collection and transportation.

On the other hand, well-designed recycling programs may influence citizens' participation in separation of household waste (Stoeva and Alriksson, 2017). Two main mechanisms/strategies - incentives and information - are mainly used to increase (municipal solid waste) recycling participation (Iyer and Kashyap, 2007; Abila and Kantola, 2019). However, lack of waste separation infrastructure, such as recycling bins, is likely to restrict the recycling behavior and intention (Yoreh, 2011; McDonald and Oates, 2003).

The contribution of urban dwellers on SWM services plays a very important role for better improvement of SWM at the community (Ezeah et al., 2013). Collaboration between the government and the community can begin with the urban community's willingness to pay some money in order to help the government to improve its SWM system/services. If people want to return to a clean development, then the community will be willing to spend some money to pay for it (Sellyanne et al., 2018). Household's willingness to pay for such services remains a question, as it depends on many factors, including their financial ability, as well as citizens' preferences and expectations about these services.

So far, in the study area (Municipality of Kozani, Greece) there is limited evidence regarding citizens' preferences, attitudes and willingness to pay for improved solid waste management services. Therefore, the aim of this study is to provide estimates, through a questionnaire survey followed by Contingent Valuation Method (CVM) of:

- the Willingess To Pay (WTP) for a "Prepaid Bag", after implementation of a "Pay As You Throw" system, as well as,
- the Willingness to Accept (WTA) compensation through a "Rewarding Recycling Program» which will make use of high - tech automatic rewarding recycling machines" respectively.

It should be noted that both systems are presented to local citizens by means of plausible and meaningful scenarios, which consider the local conditions and characteristics of the study area.

2. Literature Review

Economics valuation can assist link economic policies to environmental outcomes, give decision makers a summary of urban environmental problems and assist in formulation of policies on solid waste management (Joel et. al, 2012). According to Motta (1998), obtaining the total economic value of an

environmental asset consists in determine how much better or worse will be the people's well-being due to the changes in the quantity of environmental goods and services, either through their use or not.
The economic value is defined as the measurement of the maximum number of goods and services that an individual is willing to sacrifice in order to get another (environmental) goods or services.
Non-market resource/environmental valuation techniques can be classified into two groups/categories consisted of:

- revealed preferences- based on constructed hypothetical markets or existing markets (Christie and Azevedo, 2002; Ryan et al., 2008),
- surveys where WTP is obtained directly by asking individuals or the community about their desire to pay for goods and services produced by natural resources (stated preferences).

The Contingent Valuation Method (CVM), as the most commonly used stated preference method (Carson et al., 2001; Jin et al., 2006), is now widely accepted by resource economists, following a great deal of empirical and theoretical refinements. The application of a Contingent Valuation Method (CVM) approach consists of five (5) stages:

- Creating a hypothetical market (making a market hypothesis),
- Obtaining bids (obtaining auction value),
- Estimating Average WTP/WTA,
- Estimating bid curves (estimating the auction curve),
- Aggregating data and evaluating the CVM exercise.

Contingent Valuation Method (CVM) is based on direct expression of individuals' Willingness to Pay (maximum amount consumers are prepared to pay for a good or service) or Willingness to Accept (minimum monetary amount that a person is willing to accept to sell a good or service, or to bear a negative externality) for compensation for any change in environmental quantities, qualities or both (Bogale and Urgessa, 2012).
Several previous studies have focused on analyzing citizens': (a) participation in solid waste management (SWM) services, (b) attitudes towards solid waste management (SWM) actions and their (c) WTP for improved solid waste management (SWM). These studies are also trying to explore/identify the factors that influence household's WTP for improved solid waste management (SWM) services.
Most of these studies revealed that households' WTP for improved solid waste management services will depend on a number of socio-economic determinants, such as age, level of education, household size, income and employment characteristics.
According to Afifah et al. (2013) a very important/influential factor of WTP for waste management is the education level because in general, more educated people tend to better understand the importance of environmental protection.
The conceptual framework of the present study focuses on how to elicit: (a) households' Willingness to Pay (WTP) for a "Prepaid Bag", after the implementation of a "Pay As You Throw" system as well as (b) households' Willingness to Accept (WTA) compensation through a "Rewarding Recycling Program", which will make use of high - tech automatic rewarding recycling machines. It should be noted that both systems are presented to local citizens in the study area (Municipality of Kozani) by means of plausible and meaningful scenarios, which consider the local conditions and characteristics of the study area. Finally, the major socioeconomic factors that affect citizens' "WTP" and "WTA compensation" for the respective solid waste management systems, are adequately investigated.

3. Methods and Data

A systematic literature review was performed for the construction of a theoretical scientific reference on economic valuation applied to urban solid waste management. Based on these previous studies, it can be concluded that eliciting respondents' preferences through the Contingent Valuation Method (CVM) requires a careful survey design, the choice of the most appropriate survey mode and selection of a representative sample (Whittington, 2002).

Feitosa et al. (2008) conducted a systematic literature review, spanning the last decade, on economic valuation applied to urban solid waste management and focusing on eliciting citizens' WTP regarding improvements in urban solid waste management.

Jin et al. (2006) using a double - bounded dichotomous choice Contingent Valuation Method (DC - CVM) and a choice experiment (CE) technique aimed to examine the preferences of Macao residents for alternative urban solid waste management policies. Begum et al. (2007), employed the open - ended CVM, to assess the contractors' average maximum WTP for improved construction waste management. Also, Ferreira and Marques (2015) focused on the application of the CVM using a single bounded dichotomous choice (DC) model to elicit citizens WTP for the application of a municipal packaging waste selective collection.

Pek and Otman (2010) estimate the economic values of households' preferences for enhanced solid waste disposal services in Malaysia. An average additional monthly WTP premium in solid waste management charges was considered as a realistic payment vehicle for improved waste disposal services quality.

The analysis of households' WTP for better solid waste management services in urban areas of the urban district of Peshawar, in Pakistan, was conducted by Khattak et al. (2009), while Ojok et al. (2013) estimated households' WTP for improved municipal solid waste management services in Kampala, Uganda.

Rodrigues and Santana (2012) aimed to analyze the economic viability of a selective garbage collection system in the city of Palmas, by using the contingent valuation method. Through this (WTP) approach they tried to estimate the benefits of services for different collection systems. On the other hand, Bernad - Beltran et al. (2014) analyzed the population's attitudes towards the integration of a selective collection of biowaste into the existing municipal solid waste management system in a Spanish city. They also examined the level of citizens' participation in current waste collection systems, their willingness to participate in selective collection of biowaste, the reasons and barriers that affect their participation, their willingness to pay for the incorporation of the selective collection of biowaste and the effect of various socioeconomic characteristics on citizens' willingness to participate and willingness to pay for selective collection of biowaste.

As already mentioned, this study aims to determine the WTP for a "Prepaid Bag", after the implementation of a "Pay As You Throw System" and the WTA compensation through a "Rewarding Recycling Program which will make use of high - tech automatic rewarding recycling machines". It also aims to analyze the main factors influencing people's (respondents') WTP decisions. In order to identify these factors, the maximum willingness to pay answers are regressed against several socioeconomic characteristics of each respondent, by means of a multiple linear regression analysis.

The necessary data for this CVM study were collected through a structured web-based questionnaire survey, which aimed to predict/explain the respondents' intention to participate in waste separation and recycling processes. The survey was conducted from May 2021 to October 2021 collecting data from 456 participants. All the participants are citizens of the Municipality of Kozani (study area). It should be noted that all responses were collecting anonymously in order to protect respondents' anonymity.

The first (1st) section of the questionnaire aimed to explore citizens' perceptions by using several open - closed questions. The second (2nd) section consisted of personal (demographic and socio - economic) questions, seeking thus to find out the background information of respondents' individual characteristics, such as their: gender, age, education level, employment status, household monthly income (€), household size (i.e. number of household members). The background characteristics of respondents (demographic and socio - economic characteristics) are presented in Table 1.

4. Empirical Results

Contingent Valuation Method (CVM) was used to determine WTP and WTA values respectively. For this purpose, multiple regression analysis was performed to measure the impact of independent variables that affect WTP and WTA values, taking as dependent variables: (a) Willingness To Pay (WTP) for a

"Prepaid Bag", after the implementation of a "Pay As You Throw System" (i.e. maximum price that the respondent want to pay per prepaid waste bag) and (b) Willingness To Accept (WTA) compensation through a "Rewarding Recycling Program which will make use of high - tech automatic rewarding recycling machines" (i.e. minimum price that the respondent want to be compensated for a returning recycling package: metal, plastic and glass item of packaging). The independent variables consisted of: (a) gender, (b) age, (c) household monthly income (€), (d) education level, (e) agreement with «Polluter Pays Principle», (f) agreement with supervisory and imposition of fines, (g) household waste separation intention, (h) intention to participate in rewarding recycling.

The following figures illustrate and represent the main results of this survey, concerning:

1. Respondents' willingness to pay (WTP) for a "Prepaid Bag", after the implementation of a "Pay As You Throw System" (for the case of a garbage bag size: 52 X 75 cm, 45lt) (Figure 1)
2. The main reasons for citizens' reluctance to pay for the hypothetical prepaid waste bag system (Figure 2)
3. Respondents' intention to use the high - tech automatic rewarding recycling machines (Figure 3), as well as the reasons for citizens' reluctance to these recycling machines (Figure 4)
4. Respondents' intention to participate in a «Rewarding Recycling Program» (Figure 5) and their WTA compensation through such a program, which will make use of high - tech automatic rewarding recycling machines" (Figure6)
5. Participants' waste separation intention (Figure 7) and their agreement/disagreement with: (a) the «Polluter Pays Principle» (Figure 8), as well as with (b) the application of a monitoring system that will be able to impose fines for disobedience (Figure 9).

Table 1: Participants' demographic and socio - economic characteristics

Gender		**Household Monthly Income (€)**	
Male	45.39%	0 - 500	9.65%
Female	54.61%	500 - 1,000	30.04%
Age		1,000 - 1,500	22.15%
< 25	5.92%	1,500 - 2,000	14.25%
25 - 35	55.70%	2,000 - 2,500	10.31%
35 - 55	32.90%	2,500 - 3,000	4.39%
> 55	5.48%	>3,000	9.21%
Education level		**Household size (Family members)**	
Primary education	0.66%	1	23.24%
Secondary education	6.80%	2	28.95%
Post-Secondary education	2.63%	3	19.74%
Tertiary education	39.69%	4	23.46%
Master studies	43.20%	5	3.51%
PhD studies	7.02%	6	1.10%
Employment Status			
Student		5.04%	
Self - Employed		28.51%	
Employee		33.99%	
Public official		15.35%	
Farmer		0.44%	
Military officer		0.88%	
Unemployed		7.90%	
Retired		3.07%	
Other		4.82%	

Figure 1: Willingness to Pay (WTP) for a prepaid waste bag (WTP values)

Figure 2: Reasons for citizens' reluctance to pay for a prepaid waste bag

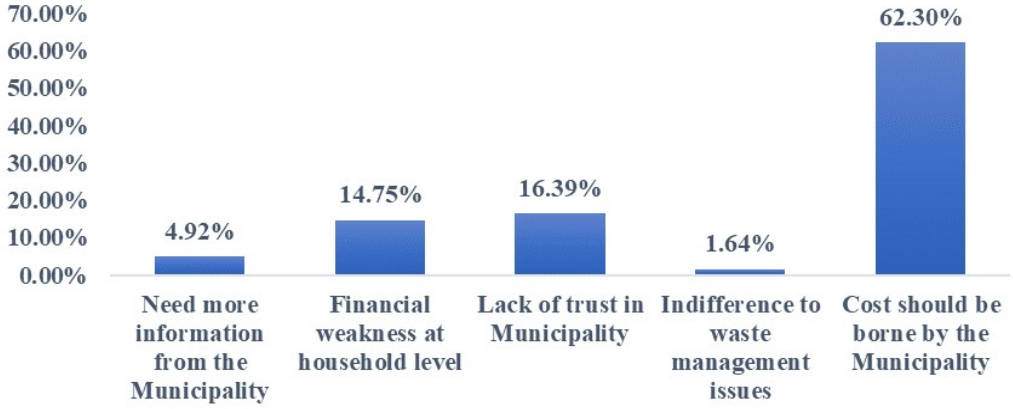


Figure 3: Use of high - tech automatic rewarding recycling machines

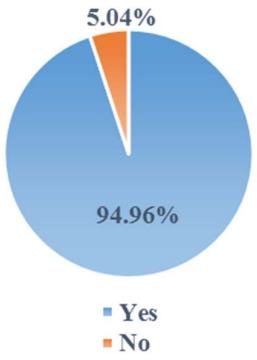


Figure 4: Citizens' reluctance to use high - tech automatic rewarding recycling machines

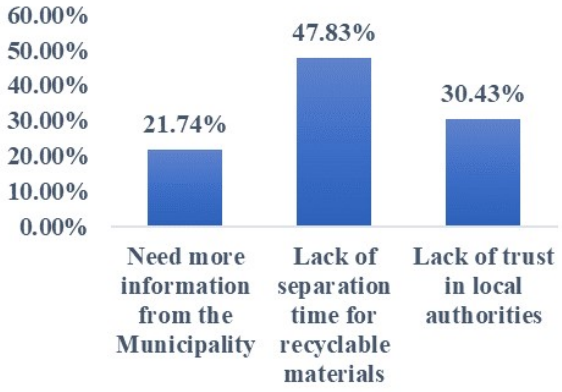


Figure 5: Willingness to Accept (WTA) compensation through a "Rewarding Recycling Program which will make use of high-tech automatic rewarding recycling machines (metal, plastic and glass item of packaging) (WTA values)

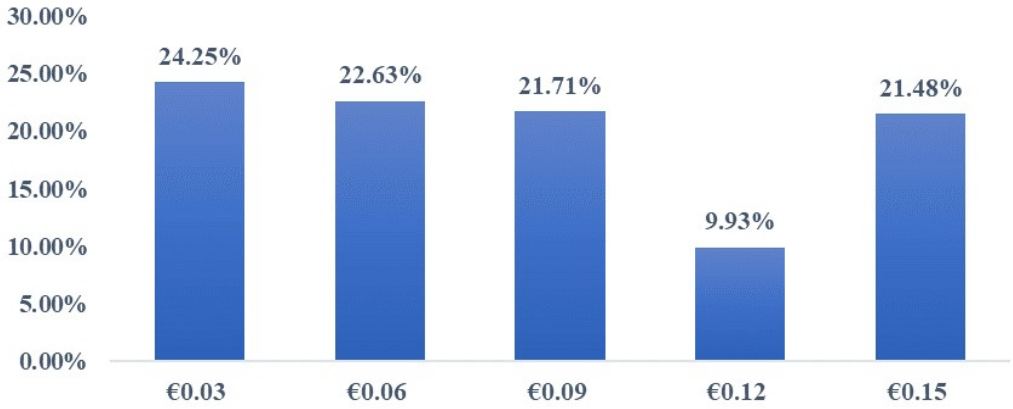


Figure 6: Participation in a "Rewarding Recycling Program"

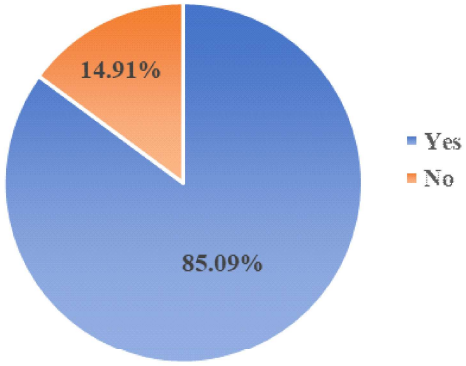


Figure 7: Participants' waste separation intention

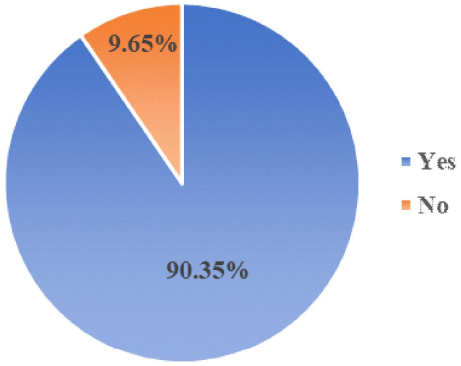


Figure 8: Agreement with the «Polluter Pays Principle»

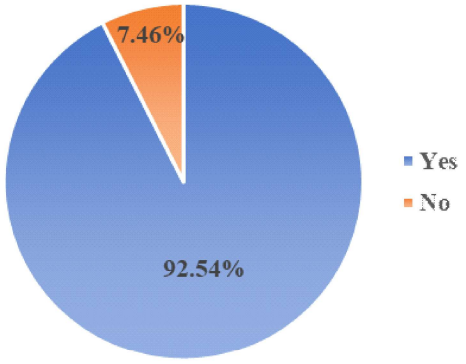
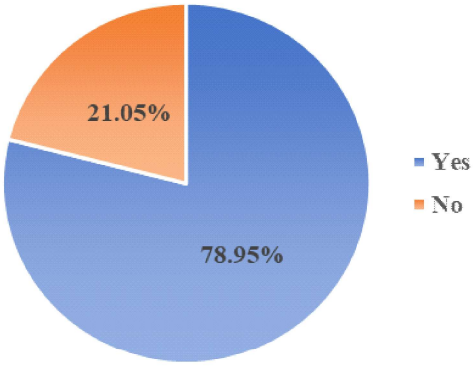


Figure 9: Monitoring and imposition of fines



In order to calculate the mean WTP and WTA values, which are crucial parameters in every CVM study, we used the stated values from Figure 1 and Figure 5. Particularly, the mean WTP value per prepaid waste bag and the mean WTA value per returning recycling package (metal, plastic, glass item of packaging) were estimated after excluding the protest votes from the total number of respondents. As protest votes were taken into account all zero-values who expressed:

- a lack of trust in local government authorities (in both WTP and WTA assessment),
- that the total cost of solid waste management should be borne by the local government authorities (i.e. by the municipality of Kozani) (only in WTP assessment).

The mean WTP value was found equal to 0.592 € per prepaid waste bag and the mean willingness to accept compensation was estimated to be equal to 0.082 € per returning recycling package. These estimates can be used as a reference in any pricing policy, which can be applied in order to ensure the necessary financial resources (i.e. to generate the funds) for the future waste management efforts.

Table 2: Mean WTP and WTA values

Mean Willingness to Pay (WTP) **(per prepaid waste bag)**	0.592 €
Mean Willingness to Accept (WTA) **(per returning recycling package)**	0.082 €

Considering the multiple linear regression analysis, we took into account the following variables/factors:

- The WTP for a "Prepaid Bag" after the implementation of a "Pay As You Throw System", was treated as the dependent variable,
- The independent variables of the model consisted of the following: (a) gender, (b) age, (c) household's monthly income, (d) education level, (e) agreement with the «Polluter Pays Principle», (f) agreement with the monitoring and imposition of fines system, (g) participants' waste separation intention

The results of the stepwise multiple linear regression analysis are presented in Table 3.

Table 3: Willingness to Pay (WTP) regression equation

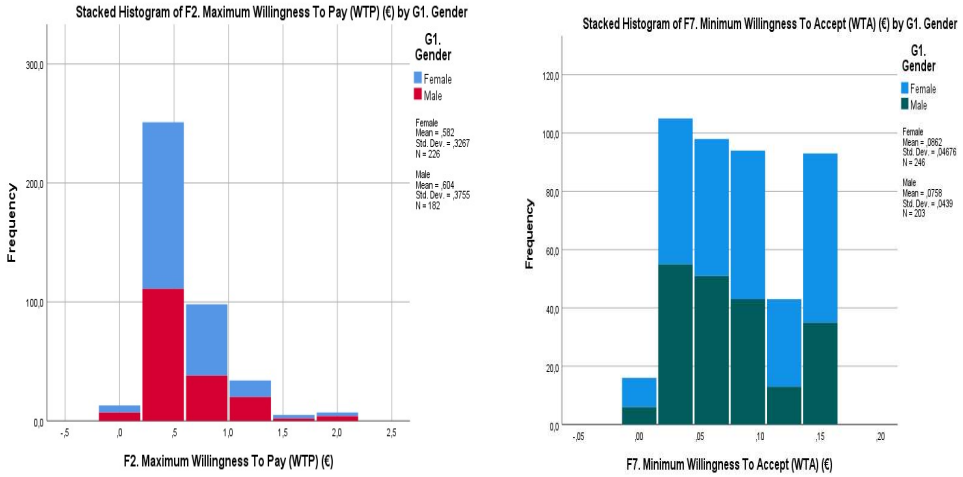
Coefficients[a]					
	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	t	Sig.
(Constant)	0.406	0.075		5.402	0.000
Agreement with monitoring & imposition of fines	0.074	0.044	0.084	1.698	0.090
Education Level	0.037	0.018	0.098	1.991	0.047

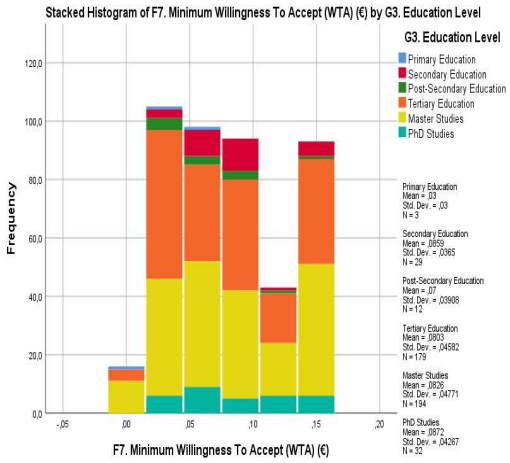
a. Dependent Variable: Willingness to Pay (WTP) (€)

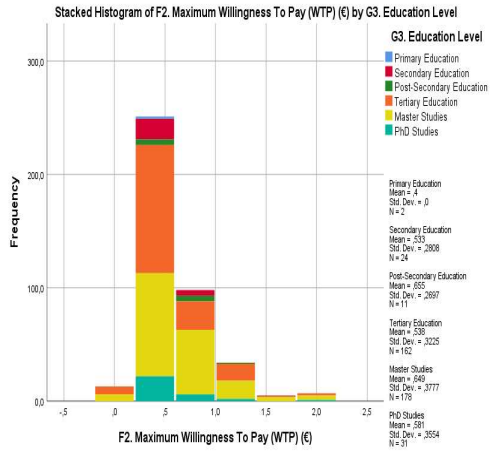
Taking into account the regression results from the above table, education seems to significantly affect citizens' WTP. Namely, education is likely to positively affect the public attitudes as it is a crucial factor in achieving higher awareness.

Finally, Figure 10 present stacked Histograms of WTP and WTA by gender and by education level (created from IBM-SPSS statistics) in order to illustrate the effect of these factors on the WTP-WTA values.

Figure 9: Willingness to Pay (WTP) for a prepaid waste bag (WTP values)







5. Conclusions

In this study, we aimed to record and analyze people's concerns regarding solid waste management in the municipality of Kozani. It also aimed to estimate the WTP for a "Prepaid Bag", after the implementation of a "Pay As You Throw System" and the WTA compensation through a "Rewarding Recycling Program, which will make use of high - tech automatic rewarding recycling machines". A structured web-based questionnaire survey was the main tool for the collection of raw data. The questions were related to the respondents' perceptions for the two aforementioned solid waste management programs.

The statistical analysis of citizens' answers revealed some remarkable results, which can be used from stakeholders in order to re-design waste management and recycling services. Specifically:

- The majority of respondents stated their WTP value for a prepaid waste bag, while only 13.38% of them expressed a protest vote (i.e. they were not willing to pay any amount for prepaid waste bags)
- The mean WTP value was estimated to be equal to 0.592 € per prepaid waste bag, while the mean WTA compensation was found equal to 0.082 € per returning recycling package, respectively.
- The majority of citizens have a positive attitude and intention to participate in both recycling rewarding programs and household waste separation programs.

Another significant outcome of this study is that the statistical analysis with regard to citizens' Willingness to Pay (WTP) values revealed the important role that education and environmental information can play in order to stimulate pre-environmental behavior with regard to individual waste reduction.

Considering the policy implication of our results, policy makers could use them in order to further evaluate the potential use of economic (market-based) instruments in order to improve the urban solid waste management in the Municipality of Kozani.

The outcomes presented here constitute the primary results of an extended investigation/research which is conducted in the Municipality of Kozani, regarding the implementation of both Pay As You Throw (PAYT) systems and rewarding recycling programs.

Overall, the results of this study aim to influence the municipal solid waste management strategy, by offering some policy directions with regard to the future implementation of efficient and social acceptable solid waste management programs.

References

Alam, P. and Ahmade, K. (2013). Impact of Solid Waste on Health and the Environment. International Journal of Sustainable Development and Green Economics (IJSDGE), (Special Issue), 2: 165-168.

Rezaei, M. R., Abdoli, M. A., Karbassi, A., Baghvand, A. and Khalilzadeh, R. (2010). Bioremediation of TNT contaminated soil by composting with municipal solid wastes. Soil and Sediment Contamination, 19; 504-514.

Medina, M. (2010). Solid wastes, poverty and the environment in developing country cities: Challenges and opportunities, WIDER Working Paper, No. 2010/23, ISBN 978-92-9230-258-0, The United Nations University World Institute for Development Economics Research (UNU-WIDER), Helsinki.

Kaza S., Yao L.C., Bhada-Tata P., Van Woerden, F. (2018). What a Waste 2.0: A Global snapshot of solid waste management to 2050. World Bank Publications, Washington, DC, USA.

Kassa, B. A. and Teshome, Y. M. (2016). Smallholder farmer's willingness to pay for improved soil and water conservation practice: A contingent valuation study in Abaro-Toga Watershed Ethiopia. American Journal of Business, Economics and Management, 3 (6), 432-441.

Sankoh, F.P. and Yan, X. (2013). Problems of solid waste management in developing urban cities: a case study of Freetown, Sierra Leone. American Journal of Environmental Protection, 2(5), 113-120.

Wilson, DC and Velis, K. (2014). Cities and waste: Current and emerging issues. Waste Management and Research, 32(9), 797-799.

Behzad, N., Ahmad, R., Saied, P., Elmira, S., Bin, M. M. (2011). Challenges of solid waste management in Malaysia, Research Journal of Chemistry and Environment, 15(2), pp. 597-600.

Karagiannidis, A. Xirogiannopoulou, A., Adinelidou, A. (2006). Waste Management and urban environment, Technical Chamber of Greece (in Greek) (available online): http://library.tee.gr/digital/kma/kma_m1364.pdf

Stoeva, K., Alriksson, S. (2017), Influence of recycling programmes on waste separation behaviour, Waste Management, 68, 732-741.

Iyer, E.S., Kashyap, R.K. (2007), Consumer recycling: Role of incentives, Information and social class. Journal of Consumer Behaviour, 6, 32-47.

Abila, B., Kantola, J. (2019), The perceived role of financial incentives in promoting waste recycling - Empirical evidence from Finland, Recycling 4(1), 1-11.

Yoreh T. (2011), Ultra - Orthodox recycling narratives: implications for planning and policy. Journal of Enterprising Communities: People and Places in Global Economy, 4(4), 323-345.

McDonald, S. Oates, C, (2003), Reasons for non-participation in a kerbside recycling scheme, Resources, Conservation and Recycling, 39(4), 369-385.

Ezeah, C., Fazakerley, J., Roberts, C. L. (2013). Emerging trends in informal sector recycling in developing and transition countries. Waste Management, 33(11), 2509-2519.

Sellyanne, D., Susetyo, D., Imelda, Bachri, F., Apriani, D., Subardin, M. (2018). The Determinant of Willingness to Pay for Waste Management in Slum Area, Proceedings of the 4th Sriwijaya Economics, Accounting and Business Conference (SEABC), pp 439-447.

Joel, S., Mark, K., Grace, J. (2012). Economic valuation of improved solid waste management in Eldoret Municipality, Journal of Emerging Trends in Economics and Management Sciences, 3: 962-970.

Motta, R.S. (1998). Manual para valoracao economica de recursos ambientais. Ministerio do Meio Ambiente, dos Recursos Hidricos e da Amazonia Lega, Brasilia.

Christie, M. and Azevedo, C. (2002). Testing the consistency in benefit estimates across contingent valuation and choice experiments: a multiply policy option application, paper presented at the 2nd World Congress of Environmental and Resource Economists, June, Monterey, California.

Ryan, M., Gerard, K., Amaya-Amaya, M. (2008). Using discrete choice experiments to value health and health care (The economics of non-market goods and resources), vol. 11, Netherlands Antilles, AN. Springer Academic Publishers, 256 pp.

Carson, D., Gilmore, A., Perry, C., Gronhaug, K. (2001). Qualitative Marketing Research.
Jin, J. J., Wang, Z. S., Ran, S.H. (2006). Comparison of contingent valuation and choice experiment in solid waste management programs in Macao. Ecological Economics, 57(3), 430-441.
Bogale, A. and Urgessa, B. (2012). Households' Willingness to Pay for Improved Rural Water Service Provision: Application of Contingent Valuation Method in Eastern Ethiopia, Journal of Human Ecology, 38 (2), pp. 145-154.
Afifah, Kurniasih Nur (2013). Kesediaan Membayar Jasa Lingkungan Air Untuk Konservasi di TWA Kerandangan Kabupaten Lombok Barat. Jurnal Ekosains Vol. V. No 2.
Whittington, D. (2002). Improving the performarce of Contingent Valuation Studies in Developing Countries, Environmental and Resource Economics, 22(1), 323-367.
Feitosa, A.K, Barden, J.E., Konrad, O. (2017). Economic valuation of urban solid waste: A review, Revista Espacios, v. 38, n.14, p. 1-13.
Begum, R.A., Siwar, C., Pereira, J.J. (2007). Factors and values of willingness to pay for improved construction waste management - A perspective of Malaysian contractors, Waste Management, 27: 1902-1909.
Ferreira, S. and Marques, R.C. (2015). Contingent Valuation Method applied to waste management, Resources Conservation and Recycling, Elsevier, vol. 99, pp.111-117.
Pek, Chuen Khee and Otman, Jamal (2010). Household Demand for Solid Waste Disposal Options in Malaysia, MPRA Paper, 23143, University Library of Munich, Germany.
Khattak, Naeem-ur-Rehman, J. Khan and I. Ahmad (2009). An Analysis of willingness to pay for better solid waste management services in urban areas of District Peshawar. Sarhad J. Agric. 25 (3): 529-535.
Ojok, J., Koech, M.K., Tole, M., Okot-Okumu, J. (2013). Households' Willingness to Pay for Improved Municipal Solid Waste Management Services in Kampala, Uganda, Science Journal of Environmental Engineering Research, Volume 2013.
Rodrigues, W. and Santana, W.C. (2012). Economic analysis of urban's systems of solid waste management: the case of selective garbage collection in Palmas, TO, Revista Brasileira de Gestao Urbana, 4(2): 299-312.
Bernad - Beltran, D., Simo, A., Bovea, M.D. (2014). Attitude towards the incorporation of the selective collection of biowaste in a municipal solid waste management system. A case study, Waste Management, 34(12).

Ground management and environmental impact.

O. Eftychiadou
Architect engineer MSc
PhD candidate in Department of Planning and Regional Development, School of Engineering, National University of Thessaly, Volos, Greece
rania_eftihiadou@yahoo.gr

Abstract
Ground is a natural resource with a very important role, both for the natural environment and for human communities. The urban ground has undergone a radical change in its physiology, while the rest of the ground is generally characterized as rural. The countryside includes elements that are natural resources, such as water, habitats, timber, etc. and therefore can be considered a natural resource itself.
The perpetually changing economic and social environment is pushing for greater exploitation of natural resources to improve human living conditions. Thus, the post-rural countryside is transformed into an idyllic place for the establishment of residence and business.
The way that land is managed determines the positive or negative effects on the environment. The assessment from the change of the most natural land uses to urban uses shows direct changes in the geomorphology, the ecosystem, and the microclimate of an area, increasing the flood activity and the heat waves, which become even more intense due to climate change.
Local sustainable development with the proper use of available natural resources seems to be a tool to address their unnecessary waste and enhance the natural environment.

Keywords: Land use change, Urbanization, Environment, Natural resources, Sustainable development.

Introduction

The ground is the cover of our planet; it is alive, it has layers and a very important functionality for the natural world of the planet, it is an ecosystem. The soil, the earth that is
trampled, is as obvious as the breathing air or the drinking water, but it is not inexhaustible.
The way the ground is managed, does not seem to be considered the limited nature of the soil, and it is actually a natural place where other life forms live. Economic activities, industry, intensive agriculture, and the reconstruction of buildings, consume the land of the planet Earth.
Ground is limited and easily loses its natural properties when covered with human structures or polluted by human activities. The loss of natural soil is done by removing the physical properties and processes. The soil characteristics that prevail after its alteration are completely different; it is not suitable for food production, emission high temperatures provoking climate change, etc.
Ground is an important natural resource that encloses most of the earth's natural resources. Urbanized land is consumed land. Given the high rates of urbanization worldwide, the consumption of natural or agricultural land is rapid.

Natural Resources & Sustainable Development

Natural resources are essential for sustaining life on the planet, but it is also an integral part of human civilization, as it is a driving force. Economy with a positive sign is based on the existence and exploitation of natural resources.
Human activity uses natural resources to produce products that meet human needs. However, natural resources are a certain amount, and they are renewed at a slower-natural pace than their consumption. "There is a close correlation between economic activities and the natural resources that exist in an area" (Spilanis G. 1995: 150). Nevertheless, there are pressures for greater use of available natural resources to feed the socio-economic system.
Specifically, the ground has also a diverse character:

- ✓ Part of the ecosystem
- ✓ Foundation and basis of evolution of our culture (literally and figuratively)
- ✓ Food machine
- ✓ Technical works installation background
- ✓ Drinking water filter
- ✓ Bank of energy resources (hydrocarbons, lignite, natural gas) and mineral wealth.

According to the FAO, 95% of food comes from the soil, ¼ of the biodiversity is housed in the soil, and ⅓ of soil is degraded. Since the surface of the earth covers ¼ of the surface of the planet and there is a large percentage for mountains and deserts it is understandable that the soil does not occupy such a large surface.

Land management

The beginning of observation of the land's problem was made by Johann-Heinrich-von-Thünen (1783-1850) through his work "Der Isolierte Staat", where he proposed a model for maximizing agricultural production in concentric zones. According to this proposal, the functions would be systematized-located in zones depending on the type of products and the distance from the city and their frequency of use.
Today, soil management is more complex, as economic pressures are stronger, but also environmental problems and risks are greater.
Poor soil management includes:

- ➢ pollution due to agriculture and industry,

- agricultural intensification, destruction of forests and wetlands and overgrazing,
- salinization, soil erosion and groundwater reduction,
- Urbanization of the soil, which causes:

    - nonporous soil,
    - fragmentation of the landscape and biodiversity, leading to limitation of species and habitat

At the same time, the escalate of extreme weather events associated with climate change is causing tensions in matters of the environment, quality of life, health, and safety.
Data from the European Commission (2012) between 1990 and 2000, showed land occupancy in the EU to be around 1,000km² per year and residential areas increased by almost 6%. From 2000 to 2006, the occupancy rate was 920km² per year and the residential areas increased by 3%. This means that from 1990 to 2006 there is an increase of almost 9%, i.e., from 176,200km² to 191,200km².

Land use change

Land use is the way the ground is managed and has the potential to determine positive or negative impacts on the natural and human environment. Changes in soil management cause significant changes in the natural environment (Vitousek, P. M., 1997; Wackernagel, M., et al., 2002). While "…the rapid collapse of the role of agriculture…" (Papadopoulos, A., Chalkias, H., & Faka, A., 2016), betrays the removal of the economy from the primary sector to an economy of service and good's reselling based in a global network.
Urban areas are the transformation of the natural environment into a structured environment, that is, it is the loss of the natural environment compared to urban areas. Land use change is primarily determined by economic, political, and social factors (Hobbs, R. J., 2000).
Significant land use change, such as the conversion of natural or arable land to urban areas, is the main concern, but there is a silent cycle of land use change involving arable land being converted into land that cultivate plants for biofuel production or natural land that is converted to arable land. Thus, land use change is more complicated than it seems at first glance as "agricultural uses are abandoned and the countryside is deformed as its ecosystems are deregulated and destroyed" (Wassenhoven K. L., 1995).
The concentration of CO_2 in the atmosphere is a result of anthropogenic emissions from fossil fuels, deforestation, and other land use practices (Bonan, G., 2012). Specific land uses provide significant social and economic benefits but result in a reduction in human well-being due to the disrupted functioning of the ecosystem (Foley, J. A., et al., 2005). Land uses are a very important factor in shaping the areas' temperature. (Eftychiadou, O., 2018).
The change of uses may seem to be a negligible act, or it concerns only locally but, the millions of actions globally have a great impact on the natural environment.

Building on natural soil, in the countryside

The ever-increasing pressures for urbanization are turning natural or rural land into urban land. Essentially, urban areas are the transformation of the natural environment into a structured environment (Benton-Short L., & Short J. R., 2009).
Cities experience common long-term and recognized environmental problems, such as overpopulation, air, water, and noise pollution (Haughton G. & Hunter C., 1996). The attractiveness of the building in the countryside is due to the lack of quality of the urban environment (aesthetics, comfort, safety, economy), so people want a home in the countryside in the fresh air and away from urban problems. Notwithstanding people's lives are so intertwined with urban culture that they transfer their urban habits to the countryside, wasting land for construction, burdening the environment with their longer movements, and bringing networks into the countryside.

Image 1: Countryside's urbanization.
Source: https://www.facebook.com/103177844367566/photos/a.103636290988388/474089397276407/

However, the construction in the countryside, apart from housing, concerns other functions that are mainly urban, e.g., industry and craft, trade, entertainment, etc. Urbanization is related to economic growth and has already occurred to a large extent in developed countries, while it continues strongly in developing countries (Regmi, A., & Dyck, J., 2001). The consumption of natural soil for the installation of urban functions has many negative effects, such as environmental, security, social and even economic. The legal background in Greece that allows construction in the countryside is one hundred years old and despite the large production of legislation, the phenomenon has become very large. "The countryside is dominated by an extensive model of construction which in combination with the lack of control of land use has led to extensive scattered construction and alteration of the landscape and the natural character of large areas" (Economou, 1997).

Image 2: Land division
Source: http://galileos.gr/kivernitika-meremetia-stin-ektos-schediou-domisi/

Ground sealing in Greece

Greece is a mountainous country, and its soil is mainly dry and rocky. According to ELSTAT data, almost 70% of the country's surface is located more than 200 meters above sea level, i.e., 2/3 of the country's land surface. Most settlements and the population in Greece are settled in the largest percentage in lowland and coastal areas of the country.

The rate of urbanization in Greece is positive and has been around 0.15% for the last five years (data YPEN). It is observed that, there are three categories of areas of interest for new construction, the middle cities, the coastal areas, and the peripheral municipalities around large urban centers. All three cases indicate the intense waste of valuable land resulting in an increase in urban land relative to natural and rural land.

According to relevant research in data from Esri Inc. (Sentinel-2 satellite), forest areas in Greece cover 36% of the country's surface, while forest areas in Europe cover 34% (EEA, 2019) and it makes sense as it is a mountainous country and these areas are not suitable for agricultural activities, and also as the economy has shifted to a more service economy there is no strong interest in urbanization these mountainous areas, so they are naturally afforested. However, the land area used for crops in Greece covers 19% (data Esri Inc.) of the territory, while the corresponding crops area in Europe correspond to 25% (EEA, 2019), which is justified also by the geomorphology of the country, which does not have a large percentage in suitable soils for crops.

The artificial surfaces in Greece constitute almost 7% (data Esri Inc.) of the territory with the main feature the large dispersion in lowland, semi-mountainous and coastal areas while the artificial surfaces concern 5% (EEA, 2019) of the European surface. Given that Greece is a predominantly mountainous country, and its plains are limited, the percentage of urbanized areas is much higher than it seems at first sight.

The rate of sealing natural soil in Greece cannot be justified either by the number of its population or by the many unused buildings located in the territory. It is land consumption without planning and limit, as the construction entrepreneurship always helps to improve the country’s economic indicators.

However, the long-term effects of pointless urbanization of the countryside are serious for both the environment and society.

Impacts

Improper management of the suburban area has not only "negative effects on the spatial organization" (Economou D., 1995), on the environment, society and even the economy. "Land use practices have played a role in… global climate change" (Houghton, R. A., Hackler, J. L., & Cushman, R. M., 2001) and these kind of land changes can alter climate characteristics in the natural environment (Bonan, G., 2012).

Further, urbanization brings substantial positive social changes, such as economic development and improved living conditions (Jin, D., 2004), but can lead to many problems, such as climate change, environmental pollution, loss of agricultural productivity and loss of landscape. The relationship between urbanization and nature is negatively correlated with habitat fragmentation causing environmental stress, and with the greatest ecosystem degradation occurring in the early stages of urbanization (Wang, W., et al., 2020).

Thus, urban areas have a negative impact on intermediate rural areas (Korcelli, P., Korcelli-Olejniczak, E., & Kozubek, E., 2008). Urbanization leads to the loss of agricultural and forest land with the destruction of natural habitats and landscapes. Surface sealing affects the natural function of water runoff by causing flooding.

Urbanized areas are not shielded to deal with problems arising from the same and/or unexpected threats posed by the nature. Building in the countryside can cause natural hazards, which take place with intensity, such as floods, storms, tornadoes, drought and excessive heat, soil erosion, altering the hydrological balance, can contaminate their surface and groundwater, habitats, increasing energy use

and pollution, causing problems in the quality of community' s life, with implications for physical and mental well-being.

The long-term consequences of continued urbanization are also social and economic. Society is losing valuable ground to bequeath in the future to the next generation, and currently has a low standard of living environment. Furthermore, in new urbanized areas there are loose social ties because of new coming residents, and there are conflicts among the users, because of different interests.

From an economic point of view, building on a rural area is a capital investment that will not pay off in the long run and will probably not depreciate the capital itself as it is very likely that these areas will be abandoned so as to turn to new areas for installation, namely just as it is now where many vacant buildings are not reused. What happens to the real estate market is something analogous to the consumption of other everyday goods, which are used for a while and then thrown away without being recycled.

The reduction of the quality of the natural and urban environment if it could be translated into economic terms would certainly present a negative amount.

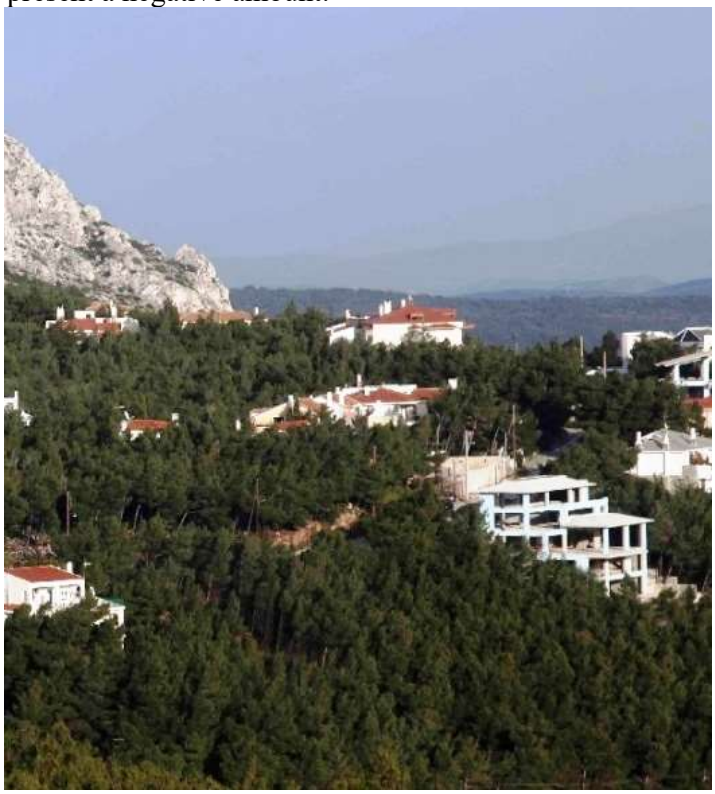


Image 3: Building in the natural land
Source: https://www.topontiki.gr/2020/09/28/ti-allazi-sti-domisi-gia-ta-ektos-schediou-akinita/

Epigrammatically the effects of ground urbanization are:

- Destruction of natural resources, such as forest, agricultural land, landscape, etc.
- Low building density (waste of valuable land)
- Improper soil management
- Enhancement of the phenomenon of global warming and the urban heat island (Eftychiadou, O., 2018)
- Ground waterproofing surface: inability to absorb water by enhancing flooding
- Burden on infrastructure and utility networks

- Annihilation of sustainable planning.
- Security issues: citizens & environmental - cultural goods
- Waste of financial resources
- Social ties reduction

Conclusions - Actions

Planning is an important tool for soil protection. The problem of agricultural land loss from urbanization should be regulated by regional planning (Morello, J., et. Al., 2000).

The empowerment of the urban areas by upgrading them through programs to become attractive for their residents but also the empowerment of the rural areas by strengthening their natural character is imperative. The logic of the circular economy should also be applied to the use of buildings and infrastructure, which should not be devalued but reused either as shells or as an already urbanized area that is reused after demolition of old buildings, redesign, and reconstruction.

The rational use of existing buildings can benefit but as well as the planning can offer to resolve issues arising from the consumption of valuable land.

Some points that could be useful to this regard are:

a) Quality in planning (environmental, aesthetic, energy, social)
b) Compliance with planning and legislation by the Administration
c) Utilization of appropriate human resources in the planning, implementation, and maintenance cycle
d) Economy of natural and financial resources
e) Non-standardization of planning studies - monitoring of good practices
f) Non-overthrow of the institutional planning, has economic, social, and environmental costs
g) Explicit prohibition and protection of areas

Local sustainable development through the proper use of available natural resources seems to be also an important tool to address their unnecessary waste and enhance the natural environment.

Urban land uses should be strengthening by avoiding complex regulatory constraints to control each case and integration of Green Infrastructure in planning.

Image 4: Ground cut for technical works
Source: https://energypress.gr/news/diagonismo-ideon-prokiryssei-i-dei-gia-ton-horotaxiko-shediasmo-tis-exoterikis-apothesis-toy

Bibliographical references

Benton-Short L., Short J. R., 2009 Cities and Nature, UK: Routledge.

Bonan G. (2012). Ecological Climatology. Concepts and Applications. UK. Cambridge University Press.

Chapin, F. S., Walker, B. H., Hobbs, R. J., Hooper, D. U., Lawton, J. H., Sala, O. E., & Tilman, D. (1997). Biotic control over the functioning of ecosystems. Science, 277(5325), 500-504.

Economou D., 1995. "Land Use and Off-Plan Construction: the Greek version of sustainability" from: Regional Development, Spatial Planning and the Environment, In the context of a united Europe, Volume II: Spatial and Regional Planning, Panteion University Athens 15-1 December 1995.

Economou, D. (1997). The planning system and rural land use control in Greece: A European perspective. European Planning Studies, 5(4), 461-476.

Eftychiadou, O. (2018). Urban heat island in Thessaloniki city, Greece: a geospatial analysis.

ELSTAT (Hellenic Statistical Authority). Accessed from: https://www.statistics.gr/

European Commission 2012 "Guidelines for best practices for limiting, mitigating or compensating for soil sealing". Belgium 2012. Πρόσβαση από το: https://ec.europa.eu/environment/soil/pdf/guidelines/pub/soil_el.pdf.

European Environment Agency (EEA), 2019 Copernicus. (Accessed from: https://www.eea.europa.eu/el/simata-eop-2010/simata-2019/arthra/arthro-tes-suntaxes-2014-ge).

Esri Inc. (Accessed from: https://www.arcgis.com/home/item.html?id=d6642f8a4f6d4685a24ae2dc0c73d4ac at 15-10-2021)

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., ... & Snyder, P. K. (2005). Global consequences of land use. Science, 309(5734), 570-574.

Haughton G., Hunter C. 1996. Sustainable Cities. 2nd ed. US: Athenaeum Press, Gateshead, Tyne and Wear.

Hobbs, R. J. (2000). Land-use changes and invasions. Invasive species in a changing world, 55-64.

Houghton, R. A., Hackler, J. L., & Cushman, R. M. (2001). Carbon flux to the atmosphere from land-use changes: 1850 to 1990. Oak Ridge: Carbon Dioxide Information Center, Environmental Sciences Division, Oak Ridge National Laboratory.

Jin, D.; Gu, S.; Shen, L. Analysis on urbanization dynamics: On factors and strategic choices of urbanization in China. China Popul. Resour. Environ. 2004, 14, 59–64.

Korcelli, P., Korcelli-Olejniczak, E., & Kozubek, E., (2008). «Typologies of European urban-rural Regions: a Review and Assessment». Geographia Polonica, 81(2), 25-42.

Morello, J., Buzai, G. D., Baxendale, C. A., Rodríguez, A. F., Matteucci, S. D., Godagnone, R. E., & Casas, R. R. (2000). Urbanization and the consumption of fertile land and other ecological changes: the case of Buenos Aires. *Environment and Urbanization*, *12*(2), 119-131.

Papadopoulos, A., Chalkias, Ch., & Faka, A. (2016). The review of the Greek countryside through a dynamic methodological approach and the utilization of geographical information systems. Social Research Review, 125 (125), 99-129.

Regmi, A., & Dyck, J. (2001). Effects of urbanization on global food demand. Changing structure of global food consumption and trade, 23-30.

Spilanis G. 1995. “Is the Environment an Inhibitory or Restrictive Parameter for Regional Development? The Necessity of Spatial Planning "by: Regional Development, Spatial Planning and the Environment, In the context of a united Europe, Volume II: Spatial and Regional Planning, Panteion University Athens 15-16 December 1995.

The Food and Agriculture Organization (FAO). Accessed from: https://www.fao.org/home/en

Vitousek, P. M., Mooney, H. A., Lubchenco, J., & Melillo, J. M. (1997). Human domination of Earth's ecosystems. Science, 277(5325), 494-499.

Wackernagel, M., Schulz, N. B., Deumling, D., Linares, A. C., Jenkins, M., Kapos, V., ... & Randers, J. (2002). Tracking the ecological overshoot of the human economy. Proceedings of the national Academy of Sciences, 99(14), 9266-9271.

Wang, W., Wu, T., Li, Y., Xie, S., Han, B., Zheng, H., & Ouyang, Z. (2020). Urbanization impacts on natural habitat and ecosystem services in the guangdong-hong kong-macao “megacity”. Sustainability, 12(16), 6675.

Wassenhoven L. K., 1995. "Spatial Planning and the Outdoor Country (or the inviolability of off-plan construction)" by: Regional Development, Spatial Planning and the Environment, In the context of a United Europe, Volume II: Spatial and Regional Planning, Panteion University Athens 15-16 December 1995.

YPEN (Ministry of Environment and Energy)

Precision Forestry Prospects in Greece

Christiana Koliouska
Laboratory of Forest Informatics, School of Forestry and Natural Environment, Aristotle University of Thessaloniki, Box 247, 54124, Greece
ckolious@for.auth.gr

Abstract
The term "Precision Forestry" (PF) describes the adoption of innovative Information and Communication Technology (ICT)) in sustainable forest management. Smart technology supports and enhance the decision making process through remote sensing, navigation systems, Geographic Information Systems (GIS), traceability, bio-economy, multicriteria analysis, precision measurement tools, wireless network, modeling and simulation, forest products supply chain management and operational research. These new trends can ensure current goals of sustainable forest management. The paper aims to explore the present status and the prospects of PF in Greek Forest Services in Macedonia. The research with the method of questionnaires was conducted in 2020. The results revealed that Forest Services should expand the ICT adoption within daily tasks and workflow. The adoption of PF is one of the most important dimensions of sustainability as it is imperative to protect forest resources while producing and using forest products to their full potential.

Keywords: Precision Forestry, Information and Communication Technology, Sustainable Forest Management, Greece, Sustainability.

JEL Codes: O1;Q01;Q23;Q56

Corporate Social Responsibility, Sustainability Reporting and Forest Fires: Evidence from the 2018 Megafires

Eleni I. Stathi & Konstantinos G. Papaspyropoulos
MSc Natural Resources: Monitoring, Technology and Bioeconomy, Department of Forestry and Natural Environment, Aristotle University of Thessaloniki, Greece
elenistathi@for.auth.gr, kodafype@for.auth.gr

Abstract
The present research explores the way that the top Greek and Californian corporations responded to the 2018 megafires, of Mati, Attica and Camp Fire, California. As megafires are becoming more often and their impacts more destructive, through the years, coordinated efforts are directed towards elimination of these tragic events and building of resilient communities. The private sector can play a vital role to achieving these goals, through philanthropic activities that are part of their Corporate Social Responsibility (CSR) and usually expressed by the corporations' sustainability reporting (SR). Based on CSR and natural disaster literature, and with the empirical data that were collected, the current research shows A) an important movement from both the Greek and Californian corporations towards the disaster relief efforts, B) the existence of different CSR patterns between the two regions and C) an extensive use of SR of the CSR performers. This is an empirical study among the first that comparatively examine CSR during two megafires in two different parts of the world and aims to add to the existing literature, as well as give a new perspective for future researchers, for corporations and public authorities.

Keywords: California and Mati wildfires; resilience; natural disasters; corporate philanthropy; GRI

JEL Codes: M14; Q01; Q23; Q56.

1. Introduction

Natural disasters are devastating events that cause severe losses of human lives, properties, damages to the environment and to cultural heritage (European Commission,2021). In the last decades, floods, heatwaves, hurricanes, wildfires and other catastrophic events that have taken place around the world, have been linked to extreme weather and climate events caused by climate change (European Commission,2021; Banholzer et al.,2014). The influences of climate change along with human interventions have greatly affected forest fires and have turned them from physical events into disastrous big burns, known as megafires (Pyne 2007, Lavorel, 2006). Even though suggestions for effective wildfire management have always been made in order to eliminate the catastrophic consequences of megafires, their extreme and unpredicted behaviour make it difficult to set them under control. With adaptation and mitigation measures, resilient communities and infrastructure can be built, thus the risks of the disasters can be reduced, crises can be faced and finally the goal for sustainability can be reached (UN, 2015). Resilience can be achieved with international cooperation and collaboration of public and private sector. Such an example is the contribution of private corporations, through philanthropic activities, when natural disasters strike. Corporate philanthropy, as part of the Corporate Social Responsibility (CSR) is a useful tool to raise resources towards the disaster relief of the affected communities (Hwang & Joo, 2021).

In 2018, the state of California experienced its deadliest megafire of all times, the Camp Fire (CAL FIRE, 2020a; CAL FIRE, 2020b). For Greece, 2018 was also a year of fatal megafires which cost the lives of 102 people (EU, 2019). Motivated by the disastrous wildfires that take place in these times, as well as the increasing need for corporations to contribute to disaster relief through CSR activities, the current study tries to understand the way that the private sector responds when megafires occur. It explores the reactions of private corporations during unexpected deadly events, like the 2018 megafires and their characteristics.

After this brief introduction, the next chapter is going to present the theoretical framework and the basic concepts of the research. In Chapter 3 the research method and the main research questions will be presented. While the answer to these questions will follow in Chapter 4, with the results of the research. The final remarks and conclusions will be included in the last chapter.

2. Literature Review

Corporations have a social role, which they express through philanthropy, having fulfilled their economic, legal and ethical responsibilities and for over fifty years, CSR literature tries to explain this behaviour (Carroll, 1991). Corporate philanthropy is expressed through donations and grants (cash or in kind) to organisations, groups or beneficiaries that aim to disaster reduction (Twigg, 2001). For their responsible behaviour corporations are accountable towards their people, their communities and the environment they operate. Through integrated reporting, i.e. sustainability reporting (SR) they communicate their CSR and disclose all the necessary information that reflect their responsible behaviour. The existence of responsible corporations is necessary to build a sustainable future, resilient and ready to face the challenges of our times.

2.1. Corporate Social Responsibility

CSR of the corporations can be well explained through stakeholder theory (Frynas & Yamahaki, 2016; Brammer & Millington, 2004) as the main goal of CSR is to create value and fulfil the corporation's responsibilities to its stakeholders (Freeman & Velamuri 2006). Recently, the theory has also been used to research CSR activities in times of natural disasters. The stakeholders' expectations seem to affect corporate donations during massive events, like Hurricane Katrina or the Wenchuan Earthquake in China (Jia & Zhang, 2015; Muller & Kraussl, 2011). It has been noticed that the reputation that corporations have among their stakeholders can lead to responsible actions when disasters strike. At the same time, the study of the different networks and groups of stakeholders can lead to the understanding

of the different patterns of CSR practices during disasters. Muller & Whiteman (2009), referring to stakeholder pressures, have found out that there is a 'home-region' and 'local presence' effect in CSR, according to which, corporations are more likely to respond to disasters that are closer to them. While they claim that 'inter-regional differences' exist in CSR during different natural disasters.

Unlike stakeholder theory, institutional theory can explain the conditions (economic and institutional) under which corporations adopt responsible behaviours (Campbell, 2007). Different CSR actions take place within different sectors or across countries. Corporations within industries with a high impact on society are more likely to adopt extensive CSR policies. By applying CSR, they legitimise their business practices and retain their reputation, according to Jackson & Apostolakou (2010). Moreover, corporations within liberal market economies, i.e. the U.S.A. or the U.K., are expected to engage with more extensive and explicit CSR activities. While corporations in coordinated market economies, like European countries, act rather implicitly (Jackson & Apostolakou, 2010; Matten & Moon, 2008).

Usually, studies merge institutional with legitimacy theory and focus on the behaviour of MNCs within different areas of the world. These studies go further than decoupling isomorphism and relate the different SCR policies of the MNCs with their try to legitimise their activities. With the approval of the parent company (sanctioned de-coupling), MNCs implement a local CSR, based on the host county's needs. The drivers may not always be the institutional pressures in the host country, as the institutional theory states. It is more about gaining acceptance and building relationships with the local society (Beddewela, 2019; Rueede & Kreutzer, 2015). In the field of corporate philanthropic disaster response, legitimacy is present with its strategic aspect. The few studies that refer to legitimacy, usually engage it with stakeholder or other theories. They recognise legitimacy as a strategic tool that corporations use in order to increase their reputation and visibility (Jia & Zhan, 2015; Gao et al., 2012).

By combining the main characteristics of CSR theories and integrating them, a wider range of questions can be answered by contemporary studies (Jia & Zhang, 2015; Muller & Whiteman 2009). In the current study, multiple aspects of SCR are studied, based on the findings of the above theories, in an effort to understand CSR of wildfire affected regions.

2.2. Sustainability Reporting

As long as the need for corporations to take over a more responsible social and environmental role raises nowadays, the integration of social, environmental and financial reporting seems necessary. SR is mainly expressed through the 'triple bottom line' model (Elkington, 1998); a model where economic, environmental as well as social information come together.

In order to track down and communicate the responsible behaviours of corporations, various initiatives have been developed through the years (Busco & Sofra, 2021) among which, the most popular is the Global Reporting Initiative (GRI) (KPMG, 2020; Landrum & Ohsowski, 2018). Up until today, the world's largest corporations have well adopted SR. Based on the KPMG's (2020) Survey of Sustainability Reporting, the majority of the corporations (80%) of the sample -of top N100 companies by revenue- use SR. There has been an increase of 56 percentage points the last twenty years, taking into consideration that in 1999, only 24% reported on sustainability matters. Among the countries with the higher SR rates, the U.S.A. score with a percentage of 98%, while Greece is one of the lowest performers with a percentage of 59%.

3. Research Method

3.1. Research Design

During the last decades Greece and California have experienced some of the most dangerous wildfires worldwide. The year 2018 was devastating, as for both of them the deadliest wildfires in their history were recorded. Extreme fire activity in inhabited areas, led to 102 fatalities during the Mati wildfire in Greece plus 85 fatalities during Camp Fire in California. This coincidence of two deadly megafires at

the same time in two different parts of the world is an opportunity to study the disaster response of private corporations and enrich contemporary CSR literature.

The sample of corporations comes from the two affected areas, given that the wildfires did not cross their country's (or state's) borders and can be rather characterised as a 'domestic natural disaster' (Johnson et al., 2011). In addition to Muller & Whiteman (2009), whose findings show that proximate to the affected regions corporations, involve more with CSR activities, the focus of the current study is on the Greek and Californian corporations that responded to the two events.

Fortune 100 (or Fortune 500) lists have proven to be a useful tool for CSR studies in times of natural disasters (Johnson et al., 2011; Muller & Kraussl, 2011; Muller & Whiteman, 2009), so this approach to sample collection has been used here too. The data of the study have been obtained from a total of 200 corporations; 100 Greek and 100 Californian that were, according to Fortune, at the top of the list.

3.2. Research Questions

Q1: Are corporations in California that adopted CSR practices more than the Greek corporations?
Q2: Are there different CSR patterns for the two regions of the study?
Q3: What is the relationship between SR and CSR during the 2018 megafires in both regions?

4. Empirical Results

The philanthropic activity of both Greek and Californian corporations was severe, in an effort to provide relief to the affected by the 2018 deadly wildfires communities. For the first question of the research to be answered, a binary variable (0,1) was used. Each time a corporation was recorded to have performed any kind of SCR activity during the 2018 megafires the variable DONATION would be equal to 1. There is no difference between the Greek and Californian corporations that adopted any kind of philanthropy, during the two megafires. In Greece, 42 corporations out of the 100 of the sample contributed to the disaster relief efforts, which is one more than the total (41) Californian corporations that acted responsibly.

The CSR activities in times of natural disasters are already known, what is not known is how the corporations in two different areas adopt them. Using the categories that have been spotted by previous literature (Johnson's et al., 2011) and with the addition of two more categories that derived from the content analysis of this study (marked with *), in order to answer the second research question there were used nine (9) immediate and five (5) long term types of CSR. Each category was used as a binary variable that would be only noted =1, in case this kind of CSR activity was observed in the sample.

Starting with the immediate CSR activities of the Greek and American corporations, Figure 1 summarises the results of the study. The Greek private sector basically acted through in-kind donations (products, services, resources) either they came from the corporations' production or they were bought, and later offered, to the affected communities. On the contrary, in California, foundations are linked to the CSR activities of the corporations. Out of the 41 corporations of the sample which donated, 14 refer to CSR actions taken by the related to the firm foundation. Consequently, more complex fundraising techniques are preferred. 'Pledges, challenge grants and foundation matched funds' are the second most noted CSR activity (18% use this type of CSR) among the Californian corporations, after 'partnerships and cash donations to NGO's' that take over the first place of the list, with a percentage of 21%.

Figure 1: Immediate CSR activities of the Greek and Californian corporations

Immediate CSR activities					
Greek corporations		%	Californian corporations		%
In-kind donations (goods, services and resources)	26	43%	Partnerships/cash donations to NGOs	21	21%
Partnerships/cash donations to NGOs	9	15%	Pledges, challenge grants and foundation matched funds	18	18%
Direct cash donations, cash grants and funds	7	11%	Employee cash donations/contributions	17	17%
Employee volunteer activities and deployment	6	10%	Direct cash donations, cash grants and funds	12	12%
Customer emergency support *	6	10%	In-kind donations (goods, services and resources)	12	12%
Employees and customers in-kind donations *	5	8%	Employee volunteer activities and deployment	10	10%
Employee cash donations/contributions	1	2%	Customer cash donations	5	5%
Customer cash donations	1	2%	Customer emergency support *	4	4%
Pledges, challenge grants and foundation matched funds	0	0%	Employees and customers in-kind donations *	1	1%

The differences between Greek and Californian long term CSR activities examined separately below (Figure 2). The term long term CSR activities expresses practices that aim to the mitigation and planning of similar disasters and those are.

Figure 2: Long term activities of the Greek and Californian corporations

Long term CSR activities					
Greek corporations		%	Californian corporations		%
Infrastructure modifications and creation of emergency operations center	17	55%	Long term funding of non-profit organizations for disaster initiatives	6	33%
Working with local leaders, community organizations, government officials	8	26%	Financial investments and corporate grants in disaster-struck communities	5	28%
Stakeholder educational and training programs	3	10%	Infrastructure modifications and creation of emergency operations center	3	17%
Financial investments and corporate grants in disaster-struck communities	2	6%	Working with local leaders, community organizations, government officials	3	17%
Long term funding of non-profit organizations for disaster initiatives	1	3%	Stakeholder educational and training programs	1	6%

The majority of the Greek corporations that practiced long term CSR have concentrated on infrastructure restoration either by providing technical services and cables to restore electricity or telecommunications, or by taking part in rebuilding initiatives of community structures. Once more, the CSR activities that are at the bottom of the Greek list are rather popular among the Californian corporations. Most of them (33%) have a network of pre-approved partner organisations that they fund systematically either directly or through foundations.

To sum up, the existence of different giving patterns between the two regions is confirmed by the current results. The role of NGOs is of main importance for the immediate CSR action of the corporations, as both the Greek and the Californian sample reported on such collaborations. As for the long term CSR activities of the corporations, differing patterns were also spotted. Once more the Greek CSR activities seemed rather 'tangible', with donor-corporations taking over infrastructure reconstructions and modifications, based on the indications of local authorities and organisations. Whereas, the Californian corporations insisted on widened financial contributions, by activating long term funds and investing in affected communities.

An extra interesting finding that came up from the data analysis is about the environmental aspect of the CSR activities during the 2018 megafires. Almost 10% of the donor-corporations (6 Greek and 2 Californian) reported on environment- oriented CSR practices.

Moving further to answering the final research question, the focus goes to the disaster responders and how well- adopted they are to SR. For that reason, only the 83 corporations that acted through CSR practices have been studied. To explore their relationship with sustainability matters, thus SR the variable REPORTING was used. This variable is a polynomial and examines the absence of SR (=0), existence of SR (=1), or more specifically the existence of GRI SR (=GRI)
With a general overview of Figure 3a it is easy to understand that the corporations that performed CSR activities related to the 2018 wildfires are rather familiar with integrated reporting. A percentage of 86,7% of them uses SR of any kind. This result indicates that the CSR performers of the sample also report on other environmental, social and corporate governance issues. Their disaster response to the 2018 megafires is part of their general CSR strategy, which they track down and publish.

Figure 3a: SR of the CSR performers

		No (0)	*%*	*Yes (1)*	*%*
REPORTING of the CSR performers	**GREECE**	8	*19%*	34	*81%*
	CALIFORNIA (US)	3	*7,3%*	38	*92,7%*
	SAMPLE (GR & CA)	11	*13,3%*	72	*86,7%*

The extended model (Figure 3b) shows that a percentage of 66,3% of the CSR performers use GRI for their reporting. For the corporations that are both reporters and CSR performers, 76,4% of them use GRI. It seems that the GRI framework is extensively used by the corporations of the sample that acted responsibly to the 2018 megafires.

Figure 3b: SR of the CSR performers (GRI model)

		No (0)	*%*	*Yes (1)*	*%*	*Yes- GRI (GRI)*	*%*
REPORTING 1 of the CSR performers	**GREECE**	8	*19%*	4	*9,5%*	30	*71,4%*
	CALIFORNIA (US)	3	*7,3%*	13	*31,7%*	25	*61,0%*
	SAMPLE (GR & CA)	11	*13,3%*	17	*20,5%*	55	*66,3%*
					(23,6%)		***(76,4%)***

5. Conclusions

The present paper explores the response of the Greek and Californian private sector, through CSR philanthropic activities, to the disaster relief effort during the 2018 megafires. The results of the research show an extensive CSR of the corporations in both regions: 42 out of a hundred top Greek s and 41 out of a hundred top Californian corporations proceeded to donations to the affected communities. It cannot be said that the Californian corporations were more responsible neither in terms of quantity nor in terms of quality. With a detailed view of each and every CSR activity of the sample, the different corporate giving patterns were found. For the Greek corporations, direct response (with in-kind donations and infrastructure restoration) was of major importance, while for the Californian corporations a more complex funding activity (with foundation matched and long-term disaster relief funds) was observed. Finally, the CSR performers of the sample seem to have a rather good relationship with SR, as 86,5% of them reported on sustainability matters at the time of the research.
Using empirical data from the two affected by wildfire regions, this research is among the first to comparative examine the real performance of the private sector in two different parts of the world when a similar natural disaster strikes. With data from the two affected regions, this study finds out that their corporations responded to the same extent in the disaster relief effort, supporting the stakeholder

theory's view that corporations 'pay more attention to disasters that are closer to home' (Muller & Whiteman, 2009).

From the institutional theory's point of view, that wants CSR to be in accordance with the different institutionalised environments that it takes place, the results are mixed. The findings of the first research question oppose to the expected results, while the findings of the second research question can have a logical explanation, based on institutional theory. According to the results of this research, Californian as part of the U.S.A., which is the top charitable country in the world, did not have a better CSR activity than Greece, which is at the bottom of the list in terms of philanthropy (based on Charities Aid Foundation's surveys, CAF,2019).

For the second research question, the existence of different CSR giving patterns between the Greek and Californian corporations of the sample is a proof of regional differences in corporate philanthropic disaster response that Muller & Whiteman (2009) recognise. The immediate disaster response of both the Greek and Californian corporations was based on partnerships with NGO's. Apart from that, the two countries reacted (immediately and long term) in a completely different way during the 2018 megafires. This finding cannot support the 'implicit-explicit' model of the institutional literature,. Nevertheless, the fact that the corporations of the sample belong to different economies can be a possible institutional explanation of this difference, as in Jackson & Apostolakou (2010).

For the SR of the CSR performers, the findings are rather encouraging, as the majority of the corporations that acted through CSR activities used some kind of SR, with the most popular GRI reporting. The integrated reporting of these corporations imply a generally sustainable performance of them. An interesting approach for future researchers, would be to examine whether CSR advantages the community or the corporations that uses them as tool of legitimacy.

Overall, this study contributes to the existing literature, with its empirical data. In some cases, it confirms prior results while in other cases it disagrees and gives the base for further study. Finally, its observations can be helpful and practically implemented for the management and planning of emergency response and the building of resilient communities.

References

Banholzer, S., Kossin, J., & Donner, S. (2014). The Impact of Climate Change on Natural Disasters. In Reducing Disaster: Early Warning Systems For Climate Change. Springer Netherlands.

Beddewela, E. (2019). Managing corporate community responsibility in multinational corporations: Resolving institutional duality. Long Range Planning, 52(6).

Brammer, S., & Millington, A. (2004). The Development of Corporate Charitable Contributions in the UK: A Stakeholder Analysis. Journal of Management Studies, 41(8).

Busco, C., & Sofra, E. (2021). The Evolution of Sustainability Reporting: Integrated Reporting and Sustainable Development Challenges. In P. Taticchi & M. Demartini (Eds.), Corporate Sustainability in Practice. Springer Nature.

CAL FIRE. (2020a). Top 20 Largest California Wildfires. In California Department of Forestry and Fire Protection.

CAL FIRE. (2020b). Top 20 Deadliest California Wildfires. In California Department of Forestry and Fire Protection.

Campbell John L. (2007). Why Would Corporations Behave in Socially Responsible Ways? An Institutional Theory of Corporate Social Responsibility. The Academy of Management Review, 32(3), 946–967.

Carroll, A. B. (1991). The Pyramid of Corporate Social Responsibility: Toward the Moral Management of Organizational Stakeholders. Business Horizons, 34(4).

Charities Aid Foundation. (2019). CAF World Giving Index.

Elkington, J. (1998). Partnerships fromcannibals with forks: The triple bottom line of 21st-century business. Environmental Quality Management, 8(1), 37–51.

European Commission. (2021). Overview of natural and man-made disaster risks the European Union may face.

European Union. (2019). Forest Fires in Europe, Middle East and North Africa 2018. https://doi.org/10.2760/1128

Freeman, R., & Velamuri, S. R. (2006). A New Approach to CSR: Company Stakeholder Responsibility. In A. Kakabadse & M. Morsing (Eds.), Corporate Social Responsibility: Reconciling Aspiration with Application (1st ed., pp. 9–23). Palgrave Macmillan.

Frynas, J. G., & Yamahaki, C. (2016). Corporate Social Responsibility: Review and Roadmap of Theoretical Perspectives. Business Ethics: A European Review, 25(3).

Gao, F., Faff, R., & Navissi, F. (2012). Corporate philanthropy: Insights from the 2008 Wenchuan Earthquake in China. Pacific-Basin Finance Journal, 20(3).

Hwang, H., & Joo, D. (2021). How to be Resilient? Local Philanthropy as a Collective Response to Natural Disasters. VOLUNTAS: International Journal of Voluntary and Nonprofit Organizations, 32(2).

Jackson, G., & Apostolakou, A. (2010). Corporate Social Responsibility in Western Europe: An Institutional Mirror or Substitute? Journal of Business Ethics, 94(3).

Jia, M., & Zhang, Z. (2015). News Visibility and Corporate Philanthropic Response: Evidence from Privately Owned Chinese Firms Following the Wenchuan Earthquake. Journal of Business Ethics, 129(1).

Johnson, B. R., Connolly, E., & Carter, T. S. (2011). Corporate social responsibility: the role of Fortune 100 companies in domestic and international natural disasters. Corporate Social Responsibility and Environmental Management, 18(6).

KPMG. (2020). The Time Has Come: The KPMG Survey of Sustainability Reporting 2020.

Landrum, N. E., & Ohsowski, B. (2018). Identifying Worldviews on Corporate Sustainability: A Content Analysis of Corporate Sustainability Reports. Business Strategy and the Environment, 27(1).

Lavorel, S., Flannigan, M. D., Lambin, E. F., & Scholes, M. C. (2006). Vulnerability of land systems to fire: Interactions among humans, climate, the atmosphere, and ecosystems. Mitigation and Adaptation Strategies for Global Change, 12(1).

Matten, D., & Moon, J. (2008). "Implicit" and "Explicit" CSR: A Conceptual Framework for a Comparative Understanding of Corporate Social Responsibility. The Academy of Management Review, 33(2), 404–424.

Muller, A., & Kräussl, R. (2011). Doing Good Deeds in Times of Need: A Strategic Perspective on Corporate Disaster Donations. Strategic Management Journal, 32(9).

Muller, A., & Whiteman, G. (2009). Exploring the Geography of Corporate Philanthropic Disaster Response: A Study of Fortune Global 500 Firms. Journal of Business Ethics, 84(4).

Pyne, S. J. (2007). Megaburning: the meaning of megafires and the means of the management. Proceedings of the Wildfire, 1-7.

Rueede, D., & Kreutzer, K. (2015). Legitimation Work Within a Cross-Sector Social Partnership. Journal of Business Ethics, 128(1).

Twigg, J. (2001). Corporate Social Responsibility and Disaster Reduction : A Global Overview. In Benfield Greig Hazard Research Centre (pp. 1–84). Benfield Greig Hazard Research Centre, DFID.

United Nations. (2015). Transforming our World: The 2030 Agenda for Sustainable Development. United Nations General Assembly, 21.10.2015, UN A/RES/70/1

National budget and environmental subsidies: Optimal management and a dynamic game

George Emm. Halkos, George J. Papageorgiou, Emm. G. Halkos, John G. Papageorgiou
University of Thessaly, Department of Economics, Laboratory of Operations Research
28 Octovriou 45, 38333, Volos, Greece
halkos@uth.gr, gp.22594@gmail.com

Abstract
In this work, we discuss first the intertemporal optimal management of subsidies offered by the environmental regulator and second the dynamic conflict between two groups of economic agents involved in environmental quality. The traditional management model with subsidies is augmented as a two–state variables model in which any taken environmental subsidy is treated as a result of historical adjustments, i.e. as a stock variable. A major implication of that model's extension is the existence of a richer equilibrium dynamics with bifurcations and limit cycles. In the second part of the work, we discuss the conflicts of the two types of players involved in the game: the first player is the social planner who cares about the good environmental quality and the second is the representative heavy equipped exploiter of the environmental resources. Both players have something common to manage that is the subsidy depending: a) on the decision of the social planner which acts according to environmental quality and the national budget and b) on the intensity of the extractors' effort.

Keywords: National budget, subsidies, environmental quality, optimal control, differential games.

JELclassifications: H61, H23, Q50, C60, C72,

1. Introduction

Dynamical economic problems can be faced either as optimal control models or as dynamic games. As it is well known the case of the dynamic games is definitively the n person extension of the case of the optimal control models at which only and only one economic agent coordinates his actions to maximize/minimize his own utility/costs. In this paper, we concern with the special fragment of the national budget stock which is offered by the social planner as subsidy while at the same time we consider the group of the economic agents that consume the given subsidy, but they do not cooperate with the social planner. Each of the above economic agents, i.e. the social planner and the group of the subsidy consumers, chooses his own policy to maximize his own intertemporal discounted utility. Since the subsidy offered it is dependent on the national budget, the strategies which are chosen by the players influence not only the levels of the utility of every player but also the common level of the national budget stock. The implications of the latter formulation could be the following. First, the strategies chosen by the economic players of the game have great implications into the size of the capital stock i.e., the national budget, which in turn has impacts on the economic magnitudes of any nation. Second, since the game is a non–cooperative, the players each other they do not coordinate their movements, but they play in a strategic way. Third, according to the game theoretic view, the result of equilibrium hinges upon the spaces of the available strategies of the players.

According to the information structure followed by the model under consideration, the players of a dynamic game have some actions to choose, i.e. to define the type of their strategies. One type of strategy is that which uses the minimum of information and based on time alone over the whole horizon the game played, which is called the open–loop strategy. On the other extreme, the closed–loop strategies are these strategies at which every player of the game adapts his actions according to the current state of the game.

Supposing that the subsidy's consumers use open–loop strategies, the only action that they have to do is to fix their trajectory of consumption and adhere to that specific orbit over the entire planning horizon, starting from time zero. Suchlike, if the social planner follows the open–loop policy pattern his only task is to plan a subsidy's offering policy at the initial time of the game and stick to that policy until the end of the game.

On the other hand, the adoption of feedback strategies requires the players of the game to adapt the time paths of their offering and consuming activities according to the current state of the stock of the national budget for the whole time horizon of the game. Feedback strategies take into account the interactions among the players in a dynamic game. If a group of subsidy consumers eats today all the subsidies offered, a fact which lowers the level of the national budget stock, the social planner plans their future actions taking into account this instantaneous change in the national budget stock. This is the rationale that the closed–loop strategies are sensitive in the strategic interactions among players.

As is well known, the subsidies are faced like public expenditures, therefore they are financed from the national budget. In turn, whenever a subsidy is offered there must be taken an equivalent measure, like taxes or like another source of public revenue, in order to balance the national budget. The offer of subsidies is not without justification and in conclusion, the choice about to offer or abolish a subsidy is a result of comparison among benefits, costs, and revenues not only social but private. As is became obvious, the subsidies mechanism tends to connect the returns between the private and public sector in such goods and services in which the observed externalities are very large.

Some examples would be the subsidies in social health e.g. inoculation against communicable diseases, in education, and especially in sustainability of the environmental amenities, e.g. sustainability of renewable and nonrenewable resources, social forestry and water conservation.

A major problem faced by the government is related with the sustainability of the fiscal deficit. To be more precise, in the case the very large fragment of subsidy is financed by borrowed funds and not by government income, then the fiscal deficit is exploding and therefore its time path becomes unstable. As a result, the main purpose of the subsidy mechanism fails and therefore has the opposite effect.

This paper aspires to contribute to the existing literature into both points of view of the subsidies' problem, i.e. first in the dynamic management model and second in the dynamic conflict of the subsidies

problem. This paper continues the novelty of the modeling at which the subsidies function is managed as a function of the accumulated national budget, extending a model that has been introduced by Halkos et al (2019). Moreover, the paper extends the modified problem in a Nash dynamic game in which we found the conditions between the discount factors of the players for the limit cycle equilibrium.
The paper has the following structure. Some useful comments on how a connection between the management of subsidies and cyclical economic actions should be are made in section 2. The extension of the one-state model in the two-state model is introduced in section 3. In section 4 is analyzed the differential game model and its limit cycle equilibrium. The conclusions are in section 5.

2. An intuitive explanation of the cyclical actions between subsidies and environmental exploitation.

The optimal growth model of Skiba of the one sector economy, for which the production function is convex-concave (Skiba, 1978), was the cornerstone of the economic literature regarding the cyclical strategies as solutions in dynamical economic models. A great example would be Wirl's model (Wirl, 1995) which extends a former renewable resources model of Clark et al (1979). The Wirl's conclusion is that the cyclical strategies of extraction are admitted as equilibrium policies even in the case at which the equilibrium points range between the intertemporal rule of exploitation and the maximum sustainable yield.
In this paper, we aim to discuss the oscillatory behavior implied by the solution of the dynamical system of the proposed model, using limit cycles and especially the stable version of the cycles. Since, as is intuitive, any orbit of a dynamical system has a basin of attraction a closed and bounded subset, with the time passing has to retrace its previous steps. Translating in policies, a subsidies' policy which offers or abolish subsidies and moreover is bounded by the restriction of the national budget sooner or later has to follow a specific one of its previous trajectories.
In a higher than the two dimensions the sufficient conditions, for the existence of stable limit cycles, is not only the existence of a pair of imaginary eigenvalues, but the first derivatives of the associated real part of the same eigenvalues are involved. More specific, in the case we deal with a $n > 2$ dimensional system tuned by a parameter μ, having also an isolated equilibrium point E_1, then the condition for Hopf bifurcations is the following: an existing simple pair of complex conjugate eigenvalues to cross the imaginary axis from left to right, while the other eigenvalues have negative real parts (Manfredi P. and Fanti L., 2004).
In economics, bifurcations are of great importance mainly because they are the outcome of the interactions between endogenous non - linear forces. Such interactions could be, according to Dockner and Feichtinger (1995), the cross effects of capital stocks and the positive growth of some economic magnitudes.
An intuitive explanation of cyclical policies in the below environmental subsidies, between the economic agents involved in environmental exploitation activities and the government, could be the following. The people who are interesting economically in the exploitation of natural resources, enjoy utility stemming from the higher intensity of their extraction mechanisms, while the opponent, i.e. the social planner, gains utility from the higher level of the restored environmental quality as a result of the subsidies which offers. We begin with a low and declining national budget. Since the social planner is benefited from a higher as possible rate of the subsidies that offer has to increase national budget up to that point at which the marginal increment would cause high unfavorable costs. Because of the national budget increment, the rate of the given subsidies is incremental and therefore the exploiters of environmental resources intensifying their exploitation actions. The latter actions would tend to stabilize the dynamical system towards the steady-state. We suppose the realistic assumption that the exploiters of the environmental resources behave myopically and therefore they accelerate the rate of their economic actions. The social planner who cares about environmental quality reacts by an incremental abolishing of subsidies. In order to avoid the loss of the previous amount of subsidies the exploiters of environmental resources has to incrementally decelerate their extraction rate and at that time the cycle of actions and counter-actions would close.

3. The extended subsidies management model

In the classical stock literature someone can be consider the management of the subsidies taken from the national budget as a stock model of two state variables, one variable could be the national budget and the second could be the subsidies offered in order to improve the environmental quality (Halkos and

Papageorgiou, 2018). In that primitive case the above optimal control model, with adjustment costs, is written as:

$$\max \int_0^{\infty} e^{-\rho t}\big[U\big(S(t),B(t)\big) - C\big(E(t)\big)\big]dt \qquad (1)$$

subject to

$$dB(t)/dt = \dot{B}(t) = g\big(B(t)\big) - S(t), \quad B(0) = B_0 \qquad (2)$$

$$dS(t)/dt = \dot{S}(t) = E(t), \qquad S(0) = S_0 \qquad (3)$$

$U\big(S(t),B(t)\big)$ is the utility function enjoyed by the social planner, $S(t)$ is the subsidies function, $B(t)$ the national budget, while $C\big(E(t)\big)$ is the cost function due to the adjustments in environmental quality, $g\big(B(t)\big)$is the growth function of the national budget and $E(t)$ is the state of environmental quality. This model admits saddle point stability in the case at which the national budget growth function has the form of the increment logistic function and moreover the conditions $U_{SS} = U_{BS} = 0$ and $g' > \rho > 0$ are met (Halkos et al, 2018).

As a continuation of the previous discussion about the primary model of subsidies, this basic two dimensional management problem consisting of equations $(1) - (3)$, can also be modified in the case the subsidies is subject to increments or reductions. The decision for increment or decrement of the overall subsidies is also highly dependent on the instantaneous existing environmental quality rate, therefore the overall amount of the subsidies it can be taken as a stock which affects directly the total subsidy function $S(t)$. But since the subsidy function $S(t)$ is a function dependent on environmental quality we denote by $S(E)$. Environmental quality E, does not remain at a given sate, but deteriorates with a simple depreciation rate. Moreover it is obvious to argue that the central manager of subsidies enjoys utility from his decision to restore environmental quality. If the social planner handles the environmental quality as a state variable, the decision to offer or abolish a subsidy would be now the new control variable which enters into the system.

With the above assumptions, the optimal control problem $(1) - (3)$ now is modified, as

$$\max_u \int_0^{\infty} e^{-\rho t}[U_1(B) + U_2(u)]dt \qquad (4)$$

Subject to $\dot{B}(t) = g\big(B(t)\big) - S(E), \qquad S(0) = S_0 \qquad (5)$

and $\dot{E}(t) = u - \delta E, \qquad E(0) = E_0 \qquad (6)$

$U_1(B),\ U_2(u)$ is the total utility applied in a separable form, i.e. is the sum of the utility derived from the existing national budget stock plus the utility stemming from the social's planner decision u . The subsidies function $S(E)$ is denoted as a function of the expected environmental quality, while δ is the depreciation rate of the environmental quality. The control (policy) variable u influences not only the changes of environmental quality in a direct way, but also affects indirectly the budget stock through the function of subsidies $S(E)$. The separable form representation of the utility function shows the intertemporal trade–off between the profits associated with the higher national budget $U_1(B)$ and the advantages stemming from environmental quality improvements, $U_2(u)$. We assume that inside utility $U_2(u)$ are embodied all the costs associated with the management of environmental amenities. Finally, the policy about environmental quality, u, is may be positive in the case of improvement or negative in the case of deterioration. The latter means that the depreciation parameter, in the steady state equilibrium, can be set to zero, which in turn implies that $u_{\infty} = 0$, i.e. no changes are made in environmental quality.

The optimal control problem (4) under the constraints $(5) - (6)$ is proceeding as follows.

The Hamiltonian is: $$H = U_1(B) + U_2(u) + \lambda_1 \dot{B} + \lambda_2 \dot{E},$$

where $\lambda_1,\ \lambda_2$ are the adjoint variables of the states $B,\ E$ respectively.
The concavity of the Hamiltonian function, both on state variables as well as on the control variable, of the problem under consideration, together with the transversality conditions are exactly the sufficient conditions for the optimality of the control problem. The limiting transversality conditions are listed below:

$$\lim_{t\to\infty} e^{-\rho t}\lambda_1 B = 0$$
$$\lim_{t\to\infty} e^{-\rho t}\lambda_2 E = 0$$

We proceed with the maximizing condition of the Hamiltonian for the control values which is given by

$$H_u = U'_2(u^*) + \lambda_2 = 0 \qquad (7)$$

And taking into account the concavity of the Hamiltonian we have

$$H_{uu} = U''_1(u) < 0$$

Taking the inverse function $h(\lambda_2) = (U'_2)^{-1}(\lambda_2)$ (which already exists), the above optimality condition is satisfied:

$$H_u(g, E, h(\lambda_2), \lambda_1, \lambda_2) = 0$$

The co-state variables $\lambda_1,\ \lambda_2$ evolve according to the following equations of motion:

$$\dot{\lambda}_1 = \big(\rho - g'(B)\big)\lambda_1 - U'_1(B) \qquad (8)$$
$$\dot{\lambda}_2 = (\rho + \delta)\lambda_2 + \lambda_1 S'(E) \qquad (9)$$

Now we are able to construct the so–called canonical system of the necessary conditions. This system is constituted by the equations (5),(6), (8), and (9), i.e. is the following system:

$$\dot{B}(t) = g\big(B(t)\big) - S(E) \qquad (10)$$
$$\dot{E}(t) = h(\lambda_2) - \delta E \qquad (11)$$
$$\dot{\lambda}_1 = \big(\rho - g'(B)\big)\lambda_1 - U'_1(B) \qquad (12)$$
$$\dot{\lambda}_2 = (\rho + \delta)\lambda_2 + \lambda_1 S'(E) \qquad (13)$$

with the following Jacobian matrix

$$J = \begin{pmatrix} g'(B) & -S'(E) & 0 & 0 \\ 0 & -\delta & 0 & -\dfrac{1}{U''_2(u)} \\ -\dfrac{g''(B)U'_1(B)}{\rho - g'(B)} - U''_1(B) & 0 & \rho - g'(B) & 0 \\ 0 & \dfrac{S''(E)U'_1(B)}{\rho - g'(B)} & S'(E) & \rho + \delta \end{pmatrix}$$

In order to compute the eigenvalues of the Jacobian matrix it is easy to apply the Dockner's formula (Dockner, 1985). Note that the four eigenvalues of the Jacobian matrix are used to characterize the linear approximation of the system (10)-(13). Applying the formula the four roots $r_{1,2,3,4}$ are:

$$r_{1,2,3,4} = (\rho/2) \pm \sqrt{(\rho^2/4) - (\Psi/2) \pm (1/2)\sqrt{\Psi^2 - 4\det J}} \quad (D.1)$$

where $$\Psi = \left\| \begin{matrix} \frac{\partial \dot{B}}{\partial B} & \frac{\partial \dot{B}}{\partial \lambda_1} \\ \frac{\partial \dot{\lambda}_1}{\partial B} & \frac{\partial \dot{\lambda}_1}{\partial \lambda_1} \end{matrix} \right\| + \left\| \begin{matrix} \frac{\partial \dot{S}}{\partial S} & \frac{\partial \dot{S}}{\partial \lambda_2} \\ \frac{\partial \dot{\lambda}_2}{\partial S} & \frac{\partial \dot{\lambda}_2}{\partial \lambda_2} \end{matrix} \right\| + 2 \left\| \begin{matrix} \frac{\partial \dot{B}}{\partial S} & \frac{\partial \dot{B}}{\partial \lambda_2} \\ \frac{\partial \dot{\lambda}_1}{\partial S} & \frac{\partial \dot{\lambda}_1}{\partial \lambda_{21}} \end{matrix} \right\| \quad (D.2)$$

Making the appropriate substitutions the coefficient Ψ of the formula $(D.2)$ reduces in to

$$\Psi = g'(B)\big(\rho - g'(B)\big) - \delta(\rho + \delta) + \frac{S''(E)U'_1(B)}{U''_2(u)\big(\rho - g'(B)\big)} (14)$$

while the determinant $\det J$ of the Jacobian reduces into the following expression:

$$\det J = -g'\delta(\rho - g')(\rho + \delta) + \frac{g''U'_1S'^2}{U''_2(\rho - g')} + \frac{S'^2U''_1}{U''_2} + \frac{g'S''U'_1}{U''_2} (15)$$

Assuming that an interior solution u^* exist for the concave problem (4) - (6) we proceed with the stability properties of the system which are dependent on basically on the sign of the rate of change of the growth function, i.e. on the sign of g', and are also dependent on the other qualitative characteristics of the model as below.

Case 1 : $g' \leq 0$, according to (15), since $g' \leq 0$, then $\det J > 0$ and $\Psi < 0$, therefore two eigenvalues must have negative real parts and consequently the long–run equilibrium is a saddle point.

Case 2 : $0 < g' < \rho$, the long–run equilibrium is characterized by the all different cases, i.e. saddle point stability, locally unstable spirals and instability such that convergence to the equilibrium is restricted to a one dimensional set of initial conditions. According to Poincare–Andronov–Hopf (PAH) theorem, the transition from a domain of stable to locally unstable may give rise to limit cycles.

Under the supposition of growth, $g' > 0$, and a diffusion process with one and only one budget point $\tilde{B}$ such that $g'(\tilde{B}) = 0$, it is well known that the time path of the budget level consists of a convex segment $(\text{if } B < \tilde{B})$ and a concave segment (if $B > \tilde{B}$). In other words, the domain of the low level $(B < \tilde{B})$ exhibits increasing returns and the domain of high level characterized by diminishing returns. It is plausible that diminishing returns lead to stable equilibrium, whereas increasing returns favour complexities, i.e. limit cycles. The reason is that a low level of national budget may increase to a certain threshold so it may be rational for the agent to expand his equipment to gain future benefits.

Specifications

We assume benefits stemming from the national budget stock to be proportional to its current level. Moreover the growth of benefits associated with the current accumulated level of environmental amenities, however, not unrestricted but rather reaches a maximum level. After all we specify the functional forms as follows:

$$U_1(B) = a_1 B, \qquad a_1 > 0 \qquad (16)$$

$$U_2(u) = \beta_1 u - \tfrac{1}{2}\beta_2 u^2, \quad \beta_1 > 0, \beta_2 \geq 0 \qquad (17)$$

$$g(B) = B(1 - B) \qquad (18)$$

$$S(E) = \gamma E, \qquad \gamma > 0 \qquad (19)$$

The last two equations represent the fact that a maximum level of the budget exists toward which B grows in the absence of subsidies, while the decline of the budget's level is proportional to the accumulated level of environmental quality E. But, in the long–run, the decision for modifications has a relative small meaning due to the high depreciation that has been made on to the past accumulated environmental quality. That is, at the steady state, the decision, u^*, tends to zero and this result is attained only setting the depreciation rate very close to zero, $\delta \approx 0$. With the last supposition and under specifications (16)- (19)the determinant of the Jacobian (15) and the coefficient Ψ (14) reduces into

$$\det J = \frac{g''(B)U'_1(B)S'^2(B)}{U''_2(u^*)\left(\rho - g'(B)\right)} = \frac{2\rho\beta_1\gamma}{\beta_2} \qquad (20)$$

$$\Psi = g'(B)\left(\rho - g'(B)\right) = \frac{a_1\gamma\left(\rho^2\beta_1 - a_1\gamma\right)}{\beta_1^2\rho^2} \qquad (21)$$

Having the set of necessary requisites for a pair of purely imaginary eigenvalues existence, i.e. $\det(J) - \left(\frac{\Psi}{2}\right)^2 - \frac{\rho^2\Psi}{2} = 0$, $\Psi > 0$ and $\det(J) > 0$, we continue choosing a_1 as the bifurcation point for the certain parameter values $\beta_1 = \beta_2 = 1, \rho = 0.01, \gamma = 0.071$. It can be shown numerically (Grass *et al*, 2008), for the above values of parameters, the conditions for complex eigenvalues with positive real parts are met for $a_1 \in (6.69\ ,\ 7.595)$, and moreover stable limit cycles exist, at least in the right–hand vicinity of $a_1 = 6.69$.
Figure 2 shows the phase portrait in the modification – stock plane that corresponds the above values of a_1

Figure 2 about here

In figure 2 the four phases **I – IV** characterizes the cycle as optimal strategy in the management problem.
Phase I: $\dot{B} > 0$ and $\dot{u} > 0$
Phase II: $\dot{B} > 0$ and $\dot{u} < 0$
Phase III: $\dot{B} < 0$ and $\dot{u} < 0$
Phase IV: $\dot{B} < 0$ and $\dot{u} > 0$

Starting with a minimum level of budget stock, Phase I is characterized by reduction in environmental quality $u < 0$ but at a diminishing rate $\dot{u} > 0$. This process implies that, in the same Phase I, decision u becomes positive at some time instant and continues to grow for sufficient level of the national budget stock. In Phase II environmental quality grows up yet when budget stock is still rising to its peak. In Phase III since the budget stock peaks its maximum value the planner gives more subsidies, but the environmental quality's high improvement now affects the budget stock which declines, so a decision to reduce environmental subsidies is taken. Finally, in Phase IV, decision u becomes negative (which in turn implies that environmental taxes imposed), meaning environmental quality deterioration, and the budget stock stops the downward fall.

4. Conflicts with a shared function of subsidies

Let us, as in previous section, denote by $B(t)$ the instantaneous budget which is in common access at time t. Without any subsidy takes place the stock of budget grows according to the function $g(B)$, obviously depending on the budget itself, satisfying the conditions $g(0) = 0$, $g(B) > 0$ for all $B \in (0, K)$, $g'(B) < 0$ for all $B \in (K, \infty)$, $g''(B) \leq 0$. In the game that follows we assume that two types

of players are involved. First player is the social planner who cares to maintain the amenities of the environment. Second player are the commercial heavy equipment extractors of environmental resources acting as factories. Carrying out exploitation of environmental resources is costly for the second type of players, e.g. damages in the available equipment, payroll for workingmen, also reducing its financial capital. Considering now the process of depletion of the budget stock (the function of environmental subsidies), does not only depend on the intensive usage $v(t)$ of the heavy equipped exploiter, but is also influenced by the environmental restoration effort $u(t)$ undertaken by the other player, i.e. by the effort of the social planner. We set as instrument variables the intensity of their extracting actions and the planner's effort respectively i.e. for the heavy equipped player (player type 2) the intensity of the extracting equipment's usage $v(t)$, and the for the social planner (player of kind 1) the effort $u(t)$, both assumed non-negatives $v(t) \geq 0, u(t) \geq 0$.
We denote the subsidies function by $S(u,v)$, also depending on both planner's effort $u(t)$and on intensity of extractors as well. Combining the growth $g(B)$ with the subsidies function $S(u,v)$ the state dynamics can be written as

$$\frac{dB}{dt} = \dot{B} = g(B) - S(u,v), \quad B(0) = B_0 > 0 \qquad (22)$$

Along a trajectory the non negativity constraint is imposed, that is

$$B(t) \geq 0 \quad \forall t \geq 0 \qquad (23)$$

A higher intensity of extracting equipment usage (for player 2) and also the higher effort of the social regulator (player 1) certainly leads to stronger depletion of the national budget (through the subsidies), so it is enough reasonable to assume that the partial derivatives of the subsidies function to be positive with respect to the parameters, i.e. $S_u > 0, S_v > 0$. Moreover the law of diminishing returns is applied only for the type 1 player's effort undertaken, that is $S_{uu} < 0$ and for simplicity we assume $S_{vv} = 0$. Additionally, we assume that the Inada conditions, which guarantee that the optimal strategies are nonnegative, holds true, i.e.

$$\lim_{u\to 0} S_u(u,v) = \infty, \qquad \lim_{u\to\infty} S_u(u,v) = 0$$
$$\lim_{v\to 0} S_v(u,v) = 0, \lim_{v\to\infty} S_v(u,v) = \infty \qquad (24)$$

The utility functions the two players want to maximize defined as follows: Player 1, the social planner, derive instantaneous utility, on one hand from its own subsiding program, but his effort $u(t)$ gives rise to increasing and convex costs $a(u)$, and on the other hand from the high stock of budget also denoted by the increasing function $\phi(B)$.
After all the present value of payer's 1 utility is described by the following functional

$$J_1 = \int_0^\infty e^{-\rho_1 t}[S(u,v) + \phi(B) - a(u)]\, dt \qquad (25)$$

Player 2, the heavy equipped extractor, enjoy utility $\upsilon(B)$ not only from the existing national budget stock $B(t)$, but also from their extracting actions intensity of use v, which is described by the function $\beta(v)$. For the utilities $\upsilon(B)$ and $\beta(v)$ we assume that are monotonically increasing functions with decreasing marginal returns, that is $\upsilon'(B) > 0$, $\beta'(v) > 0$ and $\upsilon''(B) < 0$, $\beta''(v) < 0$. We also assume that the social planner's overall effort u has no impact on the player's 2 utility. So, player's 2 utility function is defined, in additively separable form, as:

$$J_2 = \int_0^\infty e^{-\rho_2 t}[\upsilon(B) + \beta(v)]\, dt \qquad (26)$$

4.1. Periodic Solutions

In subsection that follows we make steady state and stability analysis of necessary conditions of the model which is treated as a differential game with two controls and one state. Corresponding Hamiltonians, optimality conditions and adjoint variables for the problem under consideration are respectively:

$$H_1 = S(u,v) + \phi(B) - a(u) + \lambda_1\big(g(B) - S(u,v)\big)$$

$$H_2 = v(B) + \beta(v) + \lambda_2\big(g(B) - S(u,v)\big)$$

$$\frac{\partial H_1}{\partial u} = (1-\lambda_1)S_u(u,v) - a'(u) = 0 \qquad (27)$$

$$\frac{\partial H_2}{\partial v} = \beta'(v) - \lambda_2 S_v(u,v) = 0 \qquad (28)$$

$$\dot{\lambda}_1 = \rho_1\lambda_1 - \frac{\partial H_1}{\partial B} = \lambda_1[\rho_1 - g'(B)] - \phi'(B) \qquad (29)$$

$$\dot{\lambda}_2 = \rho_2\lambda_2 - \frac{\partial H_2}{\partial B} = \lambda_2[\rho_2 - g'(B)] - v'(B) \qquad (30)$$

where subscripts denote player 1 and player 2 respectively for Hamiltonias H_i and the adjoints $\lambda_i, i = 1,2$.

Steady state solutions for the state, adjoints and controls are solutions of the system of equations:

$g(B) = S(u,v)$,
$\lambda_1[\rho_1 - g'(B)] - \phi'(B) = 0$,
$\lambda_2[\rho_2 - g'(B)] - v'(B) = 0$
$(1-\lambda)S_u(u,v) - a'(u) = 0$,
$\beta'(v) - \mu S_v(u,v) = 0$.

The Jacobian matrix of the system of optimality conditions is the following

$$J = \begin{pmatrix} \frac{\partial \dot{B}}{\partial B} & \frac{\partial \dot{B}}{\partial \lambda_1} & \frac{\partial \dot{B}}{\partial \lambda_2} \\ \frac{\partial \dot{\lambda}_1}{\partial B} & \frac{\partial \dot{\lambda}_1}{\partial \lambda_1} & \frac{\partial \dot{\lambda}_1}{\partial \lambda_2} \\ \frac{\partial \dot{\lambda}_2}{\partial B} & \frac{\partial \dot{\lambda}_2}{\partial \lambda_1} & \frac{\partial \dot{\lambda}_2}{\partial \lambda_2} \end{pmatrix} = \begin{pmatrix} g'(B) & -\frac{\partial S(u,v)}{\partial \lambda_1} & -\frac{\partial S(u,v)}{\partial \lambda_2} \\ -\lambda_1 g''(B) - \phi''(B) & \rho_1 - g'(B) & 0 \\ -\lambda_2 g''(B) - v''(B) & 0 & \rho_2 - g'(B) \end{pmatrix}$$

Which also gives the following: trace, $tr(J)$, and the determinant, $det(J)$:

$$tr(J) = \rho_1 + \rho_2 - g'(B) \quad \text{and}$$

$$\det(J) = g'(B)\big(\rho_1 - g'(B)\big)\big(\rho_2 - g'(B)\big) - \frac{\partial S(u,v)}{\partial \lambda_1}\big(\lambda_1 g''(B) + \phi''(B)\big)\big(\rho_2 - g'(B)\big) - \\ - \frac{\partial S(u,v)}{\partial \lambda_2}\big(\lambda_2 g''(B) + v''(B)\big)\big(\rho_1 - g'(B)\big)$$

According to Wirl (1997) (Proposition 4) the existence of a pair of purely imaginary eigenvalues requires that the following conditions are satisfied:

$$tr(J) > 0, \qquad \det(J) > 0, \; w > 0, \qquad \det(J) = w\; tr(J)$$

where coefficient w is the result of the sum of the following determinants

$$w = \begin{vmatrix} g'(B) & -\frac{\partial S(u,v)}{\partial \lambda_1} \\ -\lambda_1 g''(B) - \phi''(B) & \rho_1 - g'(B) \end{vmatrix} + \begin{vmatrix} \rho_1 - g'(B) & 0 \\ 0 & \rho_2 - g'(B) \end{vmatrix} +$$

$$+ \begin{vmatrix} g'(B) & -\frac{\partial S(u,v)}{\partial \lambda_2} \\ -\lambda_2 g''(B) - \upsilon''(B) & \rho_2 - g'(B) \end{vmatrix} =$$

$$= \rho_1\rho_2 - [g'(B)]^2 - \frac{\partial S(u,v)}{\partial \lambda_1}[\lambda_1 g''(B) + \phi''(B)] - \frac{\partial S(u,v)}{\partial \lambda_2}[\lambda_2 g''(B) + \upsilon''(B)]$$

The crucial condition for cyclical strategies (precisely for Hopf bifurcations to occur) is that

$$w > 0, \quad w = \frac{\det(J)}{tr\ (J)}$$

which after simple algebraic calculations reduces to

$$\rho_1\rho_2[\rho_1 + \rho_2 - 2g'(B)] = \\ = \frac{\partial S(u,v)}{\partial \lambda_1}[\lambda_1 g''(B) + \phi''(B)]\rho_1 + \frac{\partial S(u,v)}{\partial \lambda_2}[\lambda_2 g''(B) + \upsilon''(B)]\rho_2 \qquad (31)$$

4.2. Specifications for the game

We specify the functions of the game as follows: a diffusion process for the growth of the budget function, that is $g(B) = rB(1-B)$, a Cobb–Douglas type function for the subsidies function $S(u,v) = u^\gamma v$ and the utility function stemming from the intensity of the equipment's use of player 2 in the form $\beta(v) = A - v^{(\xi-1)}/(1-\xi)$. Note that the utility function $\beta(v)$ with $A > 0$ and $\xi \in (0,1)$ exhibits constant relative risk aversion in the sense of Arrow–Pratt measure of risk aversion. All the other functions are left in a linear form, i.e. both utilities stemming from the existing budget stock are for player 1 $\phi(B) = \phi B$ and for player 2 $\upsilon(B) = \upsilon B$, while the player's 1 effort cost in the linear fashion $a(u) = au$, as well. Note that all the involved coefficients, i.e. the intrinsic growth rate r and the slopes ϕ, υ and a are positive real numbers, but $\in (0,1)$, $A > 0$ and $\xi \in (0,1)$ as already mentioned.

With the above specifications the following result holds true.

Proposition 1

A necessary condition for cyclical strategies in the game between the social planner and the exploiters of the environmental resources, as described above, is the exploiters of the natural resources act more risky compared with the social planner.

Proof: See in the Appendix

The intuition behind proposition 1 is straightforward. We start with a rather low and increasing intensity of the actions undertaken of the exploiters of environmental resources, the intensity of the actions is

represented by the control variable ν. The social planner operate at a low effort, as well, because the increasing effort incurs costs, but he is worrying about the budget level, consequently for environmental quality, by reason of the intensity of the actions undertaken by the environmental exploiters. Now suppose that the exploiters react as a farsighted, he would increase the equipment's intensity only moderately and the dynamical system would approach a stable steady state. But, due to their impatience they behave myopically and react by strongly increasing the intensity of their activities. At this time the social planner, has only two choices: to leave the environmental quality deterioration or to increase his overall effort through the subsidies mechanism. Suppose that he increases the subsidies devoted to environmental quality, but the latter means that the combination of high intensity on behalf the exploiters and the higher effort (higher level of subsidies) on the planner's side leads to a strong reduction of the national budget stock.

But the low level of the national budget stock (therefore the low level of subsidies) is unprofitable for the exploiters of environmental services to work at a high intensity, therefore they have to decrease their intensity and the cycle would close. A new cycle starts again, possibly in another place because of the budget stock's reduction, but with the same results also described. In our opinion the crucial point of this intuitive explanation is that the strategic variable $u$of the first player lags behind the strategic variable ν of the second player and both are lagged behind the state variable, the national budget stock B.

4.3 An example of the game

In this subsection we calculate the Nash equilibrium of the subsidies 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

$$H_1 = S(u,v) + \phi(B) - a(u) + \lambda_1\big(g(B) - S(u,v)\big)$$
$$H_2 = v(B) + \beta(v) + \lambda_2\big(g(B) - S(u,v)\big)$$

The first order conditions, for the maximization problem, are the following system of differential equations for both players:

First, the maximized Hamiltonians are

$$\frac{\partial H_1}{\partial u} = (1-\lambda_1)S_u(u,v) - a'(u) = 0 \qquad (32)$$
$$\frac{\partial H_2}{\partial v} = \beta'(v) - \lambda_2 S_v(u,v) = 0 \qquad (32)$$

and second the costate variables are defined by the equations

$$\dot{\lambda}_1 = \rho_1\lambda_1 - \frac{\partial H_1}{\partial B} = \lambda_1[\rho_1 - g'(B)] + \phi'(B) \qquad (33)$$
$$\dot{\lambda}_2 = \rho_2\lambda_2 - \frac{\partial H_2}{\partial B} = \lambda_2[\rho_2 - g'(B)] + v'(B) \qquad (34)$$

The Hamiltonian of the player 1, H_1, is concave in the control u as far as long $\lambda_1 < 1$ and is guaranteed by the assumptions on the signs of the derivatives, i.e. $S_{uu} < 0,\ S_{vv} = 0$ and from the decreasing marginal returns on the player's 2 utilities, i.e. $v''(B) < 0,\ \beta''(v) < 0$. Moreover, optimality condition (32) implies that the adjoint variable λ_1 is positive only if the player's 1 marginal utility S_u exceeds the marginal costs, since $\lambda_1 = \big(S_u(u,v) - a'(u)\big)/S_u(u,v)$.

We also assume linearity of the model. A linear growth function, despite the critique as a fairly unrealistic model, is a good approximation for the exponential growth of the budget since 1900 (Murray, 2002). To be more precise we specify the following functions of the game in linear form:

i. the growth function of the budget in the form $g(B) = r \cdot B$, where r is the interest rate,
ii. the utility function, $\phi(B)$, which stems from the high stock of the budget, in the form $\phi(B) = \phi \cdot B$
iii. the function that measures the player's 1 effort cost in the form $u(t) = a \cdot u$

and all the constants involved are positive numbers, that is $r,\ \phi,\ a\ > 0$. From the second player's side, the functions that maximized are specified linear, i.e. the utilities arisen from the budget stock and high intensity realizations are written as

$$v(B) = v \cdot B(t) \text{ and } \beta(v) = \beta \cdot v(t) \text{ respectively.}$$

After the above simplified specifications the canonical system of equations (32) – (34) can be rewritten as follows

$$\frac{\partial H_1}{\partial u} = (1 - \lambda_1)S_u(u, v) - a = 0 \qquad (36)$$

$$\frac{\partial H_2}{\partial v} = \beta - \lambda_2 S_v(u, v) = 0 \qquad (37)$$

$$\dot{\lambda}_1 = \rho_1\lambda_1 - \frac{\partial H_1}{\partial B} = \lambda_1[\rho_1 - r] - \phi \qquad (38)$$

$$\dot{\lambda}_2 = \rho_2\lambda_2 - \frac{\partial H_2}{\partial B} = \lambda_2[\rho_2 - r] - v \qquad (39)$$

and the limiting transversality conditions has to hold

$$\lim_{t\to\infty} e^{-\rho_1 t}B(t)\lambda_1(t) = 0, \lim_{t\to\infty} e^{-\rho_2 t}B(t)\lambda_2(t) = 0 \qquad (40)$$

The analytical expressions of the adjoint variables(λ_1, λ_2), solving equations (38)-(39), are respectively:

$$\lambda_1(t) = \frac{\phi}{\rho_1 - r} + e^{(\rho_1 - r)t}C_1 \qquad (41)$$

$$\lambda_2(t) = \frac{v}{\rho_2 - r} + e^{(\rho_2 - r)t}C_2 \qquad (42)$$

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

$$\lambda_1 = \frac{\phi}{\rho_1 - r}, \quad \lambda_2 = \frac{v}{\rho_2 - r} \qquad (43)$$

To ensure certain signs for the adjoints (43) we impose another condition on the discount rates, which claim that discount rates are greater than the interest rate, i.e. we impose the condition

$$\rho_i > r, \quad i = 1,2$$

thus, the constant adjoint variables has both positive signs.
The above condition seems to be restrictive but can be justified as otherwise optimal solutions do not exist. Indeed, choosing $\rho_2 < r$, player's 2 discount rate to be lower than the interest rate, their objective functional becomes unbounded in the case they choose to carry out no exploitation. Similarly, choosing

the player's 1 discount rate lower than the interest rate the associated adjoint variable λ_1 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 $\rho_i > r, \quad i = 1,2.$
The above discussion is recorded as the next result

Proposition 2

The proposed game in its linear form admits a solution, only if the discount rates of both the players are greater than the interest rate at which the national budget grows.

Once the concavity of the Hamiltonians, with respect to the strategies and for both players, is satisfied the first order conditions guarantee its maximization. Now, we choose the subsidies function's $S(u,v)$ specification, i.e. the specification of the function that reduces the budget stock. This function is depending on both effort and intensity. We choose a similar to Cobb – Douglas production function specification, which characterized by constant elasticities, in the following form:

$$S(u,v) = u^{\sigma}v^{\zeta}, \qquad 0 < \sigma < 1 < \zeta$$

The rest of subsection is devoted to the calculations of the explicit formulas at the Nash equilibrium.

4.4. Optimal Nash Strategies
Applying first order conditions for the chosen specification function

$$S_u(u,v) = \frac{a}{1-\lambda_1} \quad \Leftrightarrow \quad \sigma u^{\sigma-1}v^{\zeta} = \frac{a}{1-\lambda_1} \qquad (44)$$

$$S_v(u,v) = \frac{\beta}{\lambda_2} \quad \Leftrightarrow \quad \zeta u^{\sigma}v^{\zeta-1} = \frac{\beta}{\lambda_2} \qquad (45)$$

The combination of (44) and (45), using the Cobb–Douglas type of specification, reveals an existing interrelationship between the strategies, that is

$$S(u^*,v^*) = (u^*)^{\sigma}(v^*)^{\zeta} \quad \Leftrightarrow \quad \frac{au^*}{\sigma(1-\lambda_1)} = \frac{\beta v^*}{\zeta\lambda_2} \quad \Leftrightarrow \quad v^* = u^*\frac{a\zeta\lambda_2}{\sigma(1-\lambda_1)\beta} \qquad (46)$$

Expression (46) 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 (68) into (67) we are able to find the analytical expressions of the strategies, after the following algebraic calculations. Expression (45) now becomes:

$$(u^*)^{\sigma+\zeta-1} = \left[\frac{a}{\sigma(1-\lambda_1)}\right]^{1-\zeta}\left(\frac{\zeta\lambda_2}{\beta}\right)^{1-\zeta}\left(\frac{\lambda_2\zeta}{\beta}\right)^{-1} = \left[\frac{a}{\sigma(1-\lambda_1)}\right]^{1-\zeta}\left(\frac{\lambda_2\zeta}{\beta}\right)^{-\zeta}$$

and from the latter the analytical expressions for the equilibrium strategies is derived in a more comparable form now:

$$u^* = \left[\frac{a}{\sigma(1-\lambda_1)}\right]^{\frac{1-\zeta}{\sigma+\zeta-1}}\left(\frac{\zeta\lambda_2}{\beta}\right)^{\frac{-\zeta}{\sigma+\zeta-1}} \qquad (47)$$

$$v^* = \left[\frac{a}{\sigma(1-\lambda_1)}\right]^{\frac{\sigma}{\sigma+\zeta-1}}\left(\frac{\zeta\lambda_2}{\beta}\right)^{\frac{\sigma-1}{\sigma+\zeta-1}} \qquad (48)$$

Further substitutions in the equation of the resource's accumulation, $\dot{B} = rB - u^{\sigma}v^{\zeta}$, yield the following steady state value of the stock

$$B_{SS} = \frac{1}{r}\left[\frac{a}{(1-\lambda_1)\sigma}\right]^{\frac{\sigma}{\sigma+\zeta-1}}\left(\frac{\zeta\lambda_2}{\beta}\right)^{\frac{-\zeta}{\sigma+\zeta-1}} \qquad (49)$$

We summarize the above discussion in a proposition.

Proposition 3

Assuming that the subsidies function exhibit constant elasticity and all the other functions to be linear, then the environmental quality game with subsidies yields constant optimal Nash strategies. The analytical expressions of the strategies are given by (47) and (48) for the social planner and the exploiters of environment respectively. The steady state value of the national budget stock is given by the expression (49).

Proposition 3 seems to be with a little economic meaning caused by the linearity of the paradigm. But the constancy of the resulting strategies can be seen in connection with the concept of time consistency, a central property in economic theory. In fact, time consistency is a minimal requirement for any strategy's credibility, but in general the open loop strategies they haven't (by definition) the time consistency property, since these strategies are not functions of the state variable but are rather time dependent functions. Nevertheless, a constant strategy may be a time consistent one, since the crucial characteristic for time consistency, i.e. the independency of any initial state B_0, is met for the above constant strategies.

5. Conclusions

In the field of stock economics the national budget stock it is a well overlooked field. As it is well known the analysis concentrates on the two basic factors that affect the national budget, namely the size of the budget itself and the rate of subsidies offered in order to sustain environmental amenities. The above specification does not take into account any other subsidies which affect the national budget, for example subsidies for poverty.

Concerning long–run equilibrium, as it is well known, the simplest case of the saddle–point type stability requires only one characteristic of the growth function of the national budget, that is the negative growth. But even the supposition of negative growth is sufficient for the saddle-point stability, the local monotonicity is not implied i.e. transient cycles may occur.

One the other hand the subsidies management is not restricted in the traditional way of the environmental quality in the glimpse of the social planner only. In order to ensure the sustainability of the environmental quality often requires the subsidies variation, i.e. the reduction or augmentation of the subsidies amount offered, and the undertaken decision about the expansion or reduction obeys onto the state variable which is the existing budget stock. Therefore, concerning national budget, as the stock variable, equilibrium dynamics becomes more complex, and much richer, also including saddle–point stability. In the discussion maid in this paper, the dynamics of such equilibrium dynamics reveals cyclical policies as optimal strategies, but from the above discussion only some conclusions has been drawn.

The emphasis given in the paper is not restricted on the stability properties of the optimal management program, but also we focus and on the stability properties of the induced nonzero sum game between two types of players, which share a common subsiding function. Precisely, the game set up between the social planner and the group of the environment exploiters with a common subsiding function yields an

economic result, for which the discount rate plays the crucial role for periodic solutions. That is, the condition for periodic solutions is that the strong equipped exploiters to be more impatient than the social planner. Finally, for the supplement linear example of the same game we compute the optimal Nash strategies for both players, which are constant expressions, therefore are time consistent strategies.

Appendix

Proof of proposition 3.

With the specifications, given in subsection 4.2, one can compute

$g'(B) = r(1-2B),\ \ g''(B) = -2r,\ \ S_u(u,v) = \gamma u^{\gamma-1},\ \ S_v(u,v) = u^{\gamma},\ \ a'(u) = a,\ \ \beta'(v) = v^{\xi-2},$
$\phi'(B) = \phi, v'(B) = v$

$\frac{\partial H_1}{\partial u} = 0 \quad \Leftrightarrow \quad (1-\lambda_1)S_u(u,v) = a'(u) \quad \Leftrightarrow \quad (1-\lambda_1)\gamma u^{\gamma-1}v = a \text{(A.1)}$

$\frac{\partial H_2}{\partial v} = 0 \quad \Leftrightarrow \quad \beta'(v) = \lambda_2 S_v(u,v) \quad \Leftrightarrow \quad \lambda_2 u^{\gamma} = v^{\xi-2} \text{(A.2)}$

Combining (A.1) and (A.2) the optimal strategies take the following forms

$u^* = \lambda_2^{-1/[1+(1-\gamma)(1-\xi)]}\left[\frac{a}{\gamma(1-\lambda_1)}\right]^{(\xi-2)/[1+(1-\xi)(1-\gamma)]} \text{(A.3)},$

$v^* = \lambda_2^{(\gamma-1)/[1+(1-\gamma)(1-\xi)]}\left[\frac{a}{\gamma(1-\lambda_1)}\right]^{\gamma/[1+(1-\gamma)(1-\xi)]} \text{(A.4)}$

and the optimal subsidy becomes

$S(u^*, v^*) = \lambda_2^{\ \ -1/[1+(1-\gamma)(1-\xi)]}\left[\frac{a}{\gamma(1-\lambda_1)}\right]^{\gamma(\xi-1)/[1+(1-\gamma)(1-\xi)]} \text{(A.5)}$

with the following partial derivatives

$$\frac{\partial S}{\partial \lambda_1} = \frac{\lambda_2^{\ \ -1/[1+(1-\gamma)(1-\xi)]}\left[\frac{a}{\gamma(1-\lambda_1)}\right]^{\gamma(\xi-1)/[1+(1-\gamma)(1-\xi)]}}{(1-\lambda_1)}\frac{\gamma(\xi-1)}{1+(1-\xi)(1-\gamma)} = \text{(A.6)}$$
$$= \frac{S(u^*,v^*)}{(1-\lambda_1)}\frac{\gamma(\xi-1)}{1+(1-\xi)(1-\gamma)}$$

$$\frac{\partial S}{\partial \lambda_2} = \frac{\lambda_2^{\ \ -1/[1+(1-\gamma)(1-\xi)]}\left[\frac{a}{\gamma(1-\lambda_1)}\right]^{\gamma(\xi-1)/[1+(1-\gamma)(1-\xi)]}}{\lambda_2}\frac{-1}{1+(1-\xi)(1-\gamma)} = \text{(A.7)}$$
$$= \frac{S(u^*,v^*)}{\lambda_2}\frac{-1}{1+(1-\xi)(1-\gamma)}$$

Both derivatives (A.6), (A.7) are negatives due to the assumptions on the parameters $\gamma,\ \xi\ \in (0,1)$ and on the signs of derivatives, i.e.

$S_u > 0, S_v > 0, v'(B) > 0, \phi'(B) > 0,$

which ensures the positive sign of the adjoints$\lambda_1,\ \lambda_2$.

Condition $w\ \ = \frac{\det(J)}{tr\ (J)}$ now becomes

$\rho_1\rho_2[\rho_1 + \rho_2 - 2g'(B)] = \lambda_1\rho_1 g''(B)\frac{\partial S}{\partial \lambda_1} + \lambda_2\rho_2 g''(B)\frac{\partial S}{\partial \lambda_2}$, which after substituting the values from (A.6), (A.7) and making the rest of algebraic manipulations, finally yields (at the steady states)

$\frac{S(u_\infty,v_\infty)g''(B)}{1+(1-\xi)(1-\gamma)}\left[\rho_1\gamma(1-\xi)\frac{\phi}{\phi+g'(B)-\rho_1} - \rho_2\right] - \rho_1\rho_2[\rho_1+\rho_2-2g'(B)] = 0 \text{(A.8)}$

Where we have set $\frac{\lambda_1}{1-\lambda_1} = \frac{\phi}{\rho_1 - g'(B) - \phi}$ stemming from the adjoint equation $\dot{\lambda}_1 = \lambda_1(\rho_1 - g'(B)) - \phi'(B)$, which, at the steady states, reduces into $\lambda_1 = \phi'(B)/(\rho_1 - g'(B))$.

Condition $w > 0$ after substitution the values from $(A.6)$, $(A.7)$ becomes

$$w = \rho_1\rho_2 - [g'(B)]^2 + \frac{S(u,v)g''(B)}{1+(1-\xi)(1-\gamma)}\left[\gamma(1-\xi)\frac{-\phi}{g'(B)+\phi-\rho_1} + 1\right] > 0 (A.9)$$

The division $(A.8)$ by ρ_1 yields

$$\frac{S(u_\infty,v_\infty)g''(B)}{1+(1-\xi)(1-\gamma)}\left[\gamma(1-\xi)\frac{\phi}{\phi+g'(B)-\rho_1} - \frac{\rho_2}{\rho_1}\right] - \rho_2[\rho_1 + \rho_2 - 2g'(B)] = 0 (A.10)$$

The sum $(A.9)+(A.10)$ must be positive, thus after simplifications and taking into account that $S(u_\infty, v_\infty) = g(B)$, we have:

$$g(B)g''(B)\frac{\rho_1 - \rho_2}{\rho_1[1 + (1-\xi)(1-\gamma)]} > [\rho_2 - g'(B)]^2$$

and the result $\rho_2 > \rho_1$ follows from the strict concavity of the logistic growth $g'' < 0$.
Since the discount rate ρ_2 of reward of the heavy equipped natural resources extractors is greater than the discount rate ρ_1 of the payoff of the social planner, it is undoubtedly safe to conclude that the second player of the game acts more risky than the first, and the risk premium is given by the difference of the two factors, i.e. $\rho_{prem} = \rho_2 - \rho_1$.

References

BERCK, P. (1981) Optimal management of renewable resources with growing demand and stock externalities, *Journal of Environmental Economics and Management*, **8**, 105 – 117.

BJORNDAL, T. (1992) *Management of fisheries as a common property resource*. Paper presented at the XXI Conference of the International Association of Agricultiral Economics, Tokyo, August 22-29.

CLARK, C. (1973) Profit maximization and the extinction of animal species, *Journal of Political Economy*, **81**, 950 – 961.

CLARK, C. (1990) *Mathematical Bioeconomics*, 2nd , Wiley Interscience.

CLARK, C.W., and G.R., MUNRO (1975) Economics of fishing and modern capital theory: a simplified approach, *Journal of Environmental Economics and Management*, **2**, 92 – 106.

DOCKNER, E. (1985) Local stability analysis in optimal control problems with two state variables, in *Optimal Control Theory and Economic Analysis*, G. Feichtingereds, Vol.2, pp. 89 – 113, North Holland, Amsterdam.

DOCKNER, E. and F., FEICHTINGER F. (1991) On the optimality of limit cycles in dynamic economic systems, *Journal of Economics*, **53**, 31 – 50.

DOCKNER, E., JORGENSEN, S., LONG, N.V. andG., SORGER, G. (2000) *Differential games in economics and management science*, Cambridge University Press.

GRASS, D., CAULKINS, J., FEICHTINGER, G., TRANGLER, G. AND BEHRENS, D. (2008) *Optimal Control of Nonlinear Processes*, Springer.

FARMER, K. (2000) Intergenerational Natural–Capital Equality in an Overlapping – Generations Model with Logistic Regeneration, *Journal of Economics*, **72**, 129 – 152.

GATTO, M., MURATORI, S. and S., RINALDI (1988) On the Optimality of the Logistic Growth, *Journal of Optimization Theory and Applications*, **57(3)**, 513 – 517.

GORDON, H.S. (1954) The economic theory of a common property resource, *Journal of Political Economics*, **62**, 124 – 142.

HANNESSON, R. (1983) A Note on Socially Optimum Versus Monopolistic Exploitation of a Renewable Resource, *Journal of Economics*, **43**, 63 – 70.

HARTLARTL, P.F. (1987) A simple proof of the monotonicity of the state trajectories in autonomous control problems,*Journal of Economic Theory*, **40**, 211 – 215.

HARTMAN, P. (1963) On the local linearization of differential equations,in *Proceedings of the American Mathematical Society*, pp. 568 – 573.

KUZNETSOV, Y. (1997) *Elements of Applied Bifurcation Theory,* Springer, Berlin.

LEVHARI, D. and C., WITHAGEN (1992) Optimal Management of the Growth Potential of Renewable Resources, *Journal of Economics*, **3**, 297 – 309.

LEWIS, T. and R. SCHMALENSEE (1979), Non – convexity and optimal harvesting strategies for renewable resources, Canadian Journal of Economics, 12 (4), 677–691

LISKI, M., KORT, P. AND A., NOVAK (2001) Increasing returns and cycles in fishing, *Resource and Energy Economics*, **23**, 241–258.

MANFREDI, P., FANTI, L., (2004) Cycles n dynamic economic modeling, Economic Modeling, 21, 573–594.

MURRAY, J.D. (2002) *Mathematical Biology I: An Introduction*, 3rd Edition, Springer.

PLOURDE, C.G. (1970) A simple model of replenishable natural resource exploitation, *American Economic Review*, **62**, 518 – 521.

PLOURDE, C.G. (1971) Exploitation of common property replenishable resources, *Western Economic Journal*, **9**, 256-266.

SCHAFER, M. (1994) Exploitation of natural resources and pollution. Some differential game models, *Annals of Operations Research*, **54**, 237 – 262.

SCOTT, A. (1955)*Natural resources: The economics of conservation*, University of Toronto Press, Toronto, Canada.

SMITH, V.L. (1969) On models of commercial fishing, *Journal Political Economy*, **77**, 181 – 198.

STROBELE, W. (1988) The Optimal Intertemporal Decision in Industrial Production and Harvesting a Renewable Natural Resource, *Journalof Economics*, **48**, 375 – 388.

STROBELE, W. andH., WACKER (1995) The Economics of Harvesting Predator – Prey Systems, *Journal of Economics*, **61**, 65 – 81.

WIRL, F. (1997) Stability and limit cycles in one – dimensional dynamic optimizations of competitive agents with a market externality, *Journal of Evolutionary Economics,***7**, 73–89.

WIRL, F. (1995) The Cyclical Exploitation of Renewable Resource Stock May Be Optimal, *Journal of Environmental Economics and Management*,**29**, 252–261.

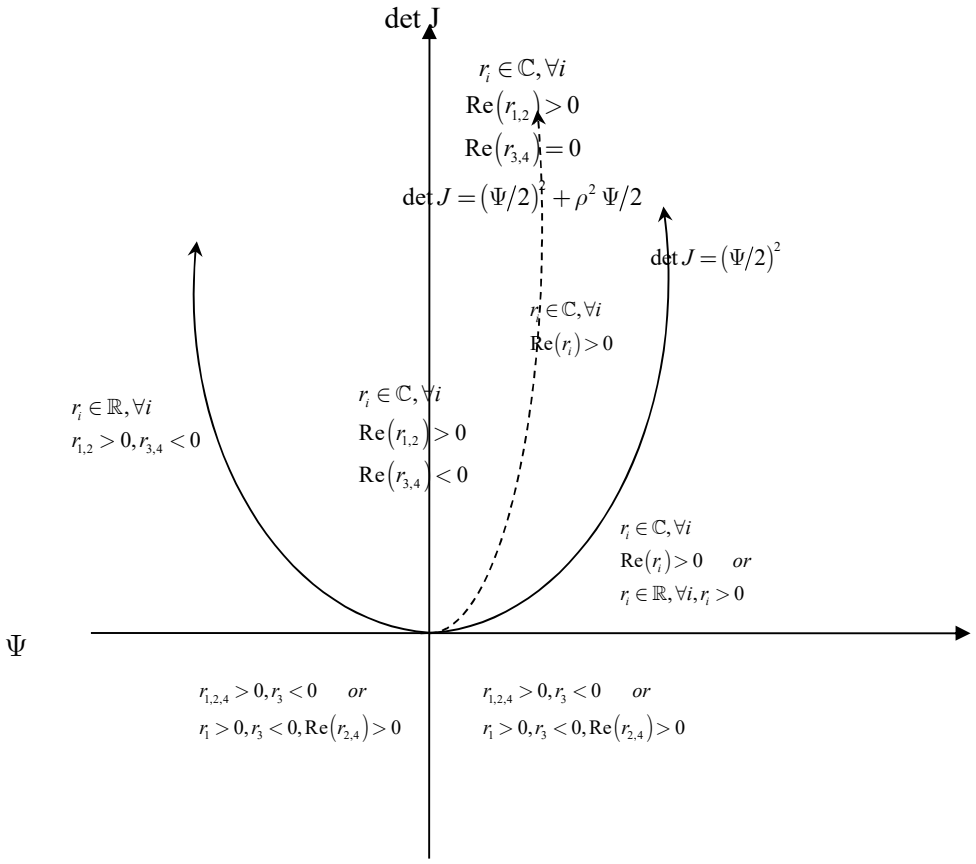


Figure 1: Classification of the eigenvalues depending on $\det J$ and Ψ.

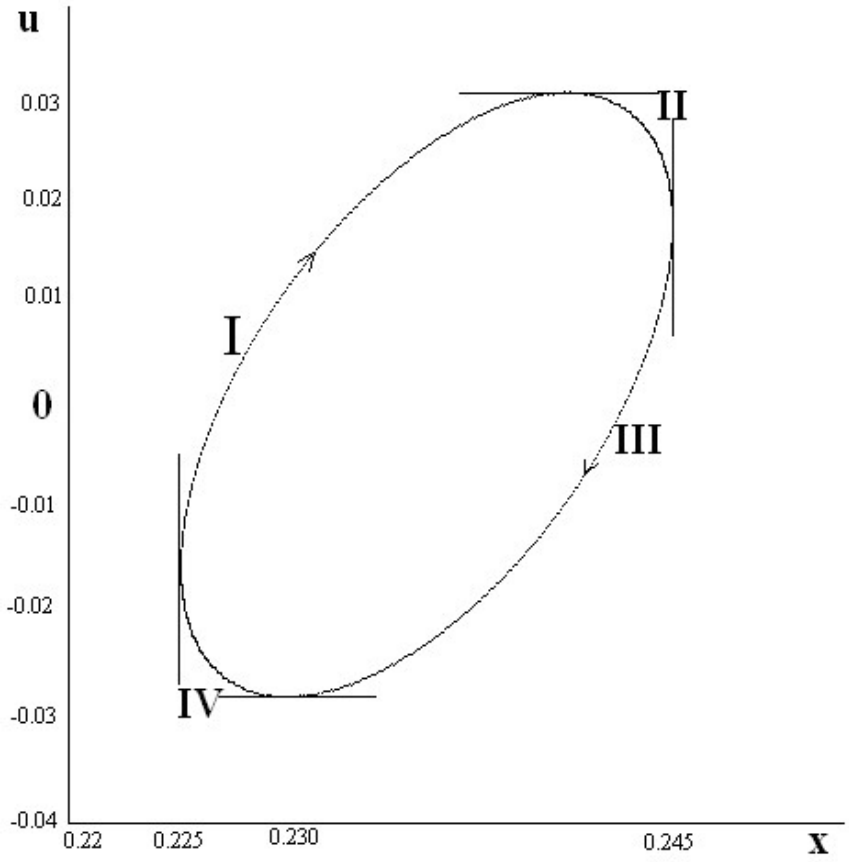


Figure 2. Phase portrait of the example of a cyclical strategy in a decision – stock plane.

The alignment of Greece with the Environmental Law of the EU: Historical development, current trends and critical implications

Georgios A. Moutsinas, Georgios Meletiadis, Dimitrios S. Prampromis, Zoi Patetsou, Konstantinos D. Patitsas & Sophoklis E. Dritsas
University of Thessaly, School of Agricultural Sciences,
Department of Ichthyology and Aquatic Environment,
Fitokou St. – Nea Ionia, 38446, Volos, Greece
gemoutsi@uth.gr, gmeletiadis@uth.gr, zoipatets@uth.gr, dprampromis@uth.gr, kpatitsas@windowslive.com, dritsas@uth.gr

Abstract
We are living in an age, where the connection between the concepts of "environment" and "justice" is disputed in terms of its very existence and practical application. At the same time, the force of environmental law is encountered in a variety of institutional organizations internationally, among which the European Union and its cohesive member states play a pivotal role, albeit with differences amid its Community partners. In the present paper, the compliance of Greek environmental law with the European one is studied in the light of intragenerational and intergenerational justice. Methodologically, a systematic review of 106 institutional documents and scientific bibliographic references was carried out. The findings of the research showed both the existence of appropriate institutional mechanisms at Community and domestic level, as well as the chronic shortcomings of Greece in relation to the unhindered implementation of the European environmental regulations. Consequently, the need to redefine national policies so as to be characterized by an explicit ecological orientation and to update the investigated issue in the context of the current coronavirus pandemic emerges.

Keywords: Environmental Law, European Union, Greece, intragenerational justice, intergenerational justice.

JEL Codes: K32;Z18;N44;Q56;Q58.

Environmental taxes and their use in European Union

Stavros Tsiantikoudis[1], Spyros Galatsidas[1], Anastasia Paschalidou[1], Eleni Zafeiriou[2], Garyfallos Arabatzis[1]

[1]Democritus University of Thrace, Faculty of Agricultural and Forestry Science, Dept. of Forestry and Management of the Environment and Natural Resources, Pantazidou 193, Orestiada

[2]Democritus University of Thrace, Faculty of Agricultural and Forestry Science, Dept. of Agricultural Development, Pantazidou 193, Orestiada

stsianti@fmenr.duth.gr, sgalatsi@fmenr.duth.gr, apascha@fmenr.duth.gr, ezafeir@agro.duth.gr, gapamp@fmenr.duth.gr

Abstract

The intensive use of natural resources, due to various economic activities, has increased the negative environmental footprint of human on earth and greatly threatens the natural environment and human societies. Gradually, sustainable management and environmental protection is emerging as one of the most important priorities for governments, both at European Union level and globally. Almost all EU Member States are now designing and implementing some of the most comprehensive and effective economic tools in which they try to meet the obligations arising from the increasingly strict European environmental legislation. Environmental taxes, which implemented in every EU country, are playing an increasingly important role to their economies. By using these taxes, state governments are trying to effectively manage the issue of protecting the natural environment and restore areas already affected by pollution. The purpose of this work is to analyze the revenues from environmental taxes for projects and actions dedicated to environmental protection and minimizing the degradation by human activities in European Union countries. The practical implementation of environmental taxation is evaluated and conclusions are drawn for the most efficient use of environmental taxes.

Keywords: Environmental taxes, European union, environmental protection activities, income

JEL Codes: H23;O13;Q56

Aspects of environmental policies in Athens during the Classical period under an economics perspective

George E. Halkos*, Emmanouil M.L. Economou and Nicholas C. Kyriazis*****
Department of Economics, University of Thessaly
28 Octovriou 45, 38333, Volos, Greece
halkos@uth.gr, emmoikon@uth.gr, nkyr@uth.gr

Abstract
In this paper we present a series of environmental policies that were implemented in the city-state of Athens during the Classical period (508-323 BCE) under an economics perspective. We link these environmental policies to the provision of public goods and we argue that such goods proved to have been beneficial for the Athenian society as a whole. They basically included the implementation of efficient hygiene and waste management policies in general. Our results show that the success of these environmental institutions should be attributed to their effectiveness but also, and equally important, to the willingness of the people themselves to accept and adopt them through a spirit of a developing a consistent environmental awareness mentality.

Keywords: Environmental institutions, Environmental public goods, hygiene, recycling, waste management policy, game theory, Classical Athens

JEL Codes: H41;I18;K32;N13;N53;Q53;Q58

* Professor, Dr., Department of Economics, University of Thessaly, 28th October 78 Street, Volos, Thessaly, Greece and Director of the Operations Research Laboratory at the same. e-mail: halkos@uth.gr
** Adjutant Lecturer at the same. e-mail: emmoikon@uth.gr
*** Professor Emeritus at the same. e-mail: nkyr@uth.gr

1. Introduction

In this paper we present some aspects of a series of environmental policies that were implemented in the city-state of Athens during the Classical period (508-323 BCE) under an economics perspective. We link these environmental policies to the provision of public goods and we argue that such goods proved to have been beneficial for the Athenian society as a whole. They basically included: i) the implementation of hygiene practices through a system of public baths in both at a personal basis and as a collective opportunity for all the residents of the Athenian city-state ii) the implementation of a recycling process regarding animal manor iii) the implementation of an effective waste management policy.

Regarding the first issue, the implementation of hygiene practices that are related to satisfactory levels of health, this is also related to Environmental Economics: people cannot live well and economically thrive if the condition of the environment does not secure the basic precondition of leaving a healthy life, a least for the majority of a society's population. Pollution further is a deterrent to economic development (Halkos 2011). Thus, clean technologies, such as what in nowadays is characterized as *green growth policies*, are related to population growth and economic development (Smulders et al. 2014).

The second issue that is analyzed in this paper is related to what we nowadays characterize as recycling processes. Effective recycling procedures are related to waste management, that is, the reduction of hazardous waste and environmental protection (Schenkel, 1993; Peretz, et al. 1997). Recycling procedures are further related to economic efficiency and growth (Shinkuma and Managi 2011). In Section 4 we provide evidence for a profitable recycling procedure that the Athenians introduced and we link this finding with a game theoretical analysis which connects the Athenian environmental institutions to profitability prospects, that is, the collection and the recycling of garbage for making profit.

What we mainly describe in this paper is that the above environmental policies were implemented in Classical Athens, even if in a primitive way, and that their success should be attributed to the implementation of an efficient package of institutions that were specifically linked to environmental management policies. We further argue that the success of these institutions was further reinforced by the willingness of the people themselves. Put it differently, the environmental institutions that the Athenians developed may not have flourished if the residents who lived in Athens themselves had not developed an 'environmental conscience' which encouraged the efficient implementation of such policies.

Of course, the success by the provision of environmental goods is related to the existence or not of efficient, robust and enforceable institutions. In fact this is a key principle which is crucial for the success of a policy in general, that exceeds the field of *Environmental Economics*. For example, under an *Institutional Economics* point of view, efficient and functional institutions are an important determinant for achieving long term economic growth (see e.g. North 1981, 1990; Acemoglu and Robinson 2013; Hodgson 2015). But what is equally crucial is the development of an environmental conscience in a society (see among others, Clayton et al., 2017; Fabi et al. 2017; Asilsoy and Oktay 2018; Gkargkavouzi et al. 2019). This is of course a behavioral issue. In general, building a collective social behavior (such as a collective environmental culture in our case), requires common protocols of behavior such as rules, norms and routines, what Nelson and Winter (1982: 14–15) characterized as "regular and predictable behavioral patterns" (see also Hodgson (2015) among others). This is of course not the main topic of our analysis here, but we provide some further elaboration on this issue in Sub-section 3.3.

Our paper is organized as follows: In Section 2 we describe the Athenian economy in brief. We think that this is necessary so that the reader can have a clearer picture regarding the Athenian economic institutions. This is important so as to better understand the logic through which the Athenians developed the sophisticated (for the era) set of environmental institutions that are described Section, in accordance to their economic implications. In Section 3 we primarily focus on the *koprologoi* and the *astynomoi* environmental institutions and the recycling policies and waste management procedures that were adopted by the Athenians. Section 4 concludes.

2. The Athenian economy in brief

During recent years, scholars have researched various aspects of the Athenian economy of the Classical period (508-323 BCE), showing its modern character and institutional set up in many areas. For example, Lyttkens (2013) and Bresson (2016a, b) among others, analyzed the structure of institutions and markets. Bresson (2016a, b), Bitros et al. (2020), Halkos et al. (2021) and Economou et al. (2021a,b) shed more light on the critical issue that, in actuality, the Athenian economy functioned as a primitive version of a market type of an economy where institutions such as the demand and supply mechanism, or public magistrates who protected the market against profiteering did truly exist. Bitros and Karayannis (2008) further analyzed the related issue of entrepreneurship in Athens under free market economy principles.

Furthermore, Economou and Kyriazis (2017) focused on the creation of an institutional set up in Classical Athens where property rights were protected and the validity of commercial contracts was backed up by law in case two traders ended up in court. Of course eminent scholars such as Hodgson (2015) have argued in general that property rights protection is a very essential prerequisite so that commercial transactions become credible. Ober (2008) adds that this attitude in Athens effectively reduced transactional costs under the Coasian logic.

In Addition Cohen (1992) in his seminal book the *Athenian Economy and Society: A Banking Perspective* analyzed exhaustively the sophisticated way banks functioned in Classical Athens. Amemiya (2007) and Bitros et al. (2020) among others, further supported the views of Cohen (1992) while Amemiya (2007) and Acton (2014) provided evidence regarding insurance services that were linked to the loans provided by the banks for performing efficiently international commercial transactions. Acton (2014) further described the existence of a primitive version of joint stock companies. These companies were important for the promotion of the very extensive international commercial transactions between the city-state of Athens with other states and of course among Athens and, according to Figueira (1998, 52), its more than 316 allies in the Delian League during the Classical period. These developments led the Athenian economy to achieve economic growth, at least for some periods between 508 to 323 BCE (see among others, Ober (2008), Bresson (2016a, b), Harris and Lewis (2016), Woolmer (2016) and Bitros et al. (2020) on this).

A very productive and extensive commercial network was established with Piraeus, the port of Athens, functioning as an international entrepôt of its times. The *Delian League* functioned during the 478-404 BCE. Under it Athens had actually managed to integrate a large part of the East Mediterranean region into a unified area of economic cooperation. This was benefited and flourished by a network of parallel currencies being used of, where the famous Athenian drachma was the dominant one (Figueira 1998; Bresson 2016b; Harris and Lewis 2016; Woolmer 2016; Bitros et al. 2020; Economou et al. 2021a, b; Halkos et al. 2021). The widespread usage of owls by Athens and its allies created an enormous conglomeration of interdependent markets that lead to a regional economic integration between them with Athens being the paramount commercial metropolis among them.

Bitros et al. (2020) further analyzed how decisions on public finance and public spending were taken by the two most important Athenian policymaking institutions, the Athenian Assembly of citizens (known as *Ecclesia*) and the *Council of the Five Hundred*[5] (known as *Boule*). Economou and Kyriazis (2019) argue that the process of transformation of the Athenian economy from an agrarian into a maritime economy during the Classical period lead also to "industrialization" in a variety of areas such as the development of primitive versions of small industries such as metalwork, the shipping industry silver mining, ceramics, carpentry, paints, fabrique, etc. and according to Halkos and Kyriazis (2010) all these procedures made Athens the first economy in history where "services" and "industrial" (handicrafts) sectors contributed more to (what we nowadays call) GDP than agriculture.

[5] For the working of the two main political institutions in Classical Athens, the *Assembly* and the *Council of the Five Hundred*, as well as the rest of the Athenian political institutions see among others, the pivotal works of Hansen (1999), Ober (2008) and Cartledge (2016), as well as Bitros et al. (2020) among others.

The above references consist only a small part of the international bibliography in the last 30 years that revisits the older, though influential, views of M. Finley (see e.g., Finley 1973, 1983) and his followers who argued that the Classical Athenian (and by extension ancient Greek) economy was characterized by primitive structures and organization and that it was "embedded" on social, political and religious aspects, meaning that it was not actually a market economy where actors behave under a *rational choice* perspective.

3. The provision of environmental public goods and services in Classical Athens

Bitros et al. (2020) provide interesting evidence regarding the issue of the partial provision of a series of public goods in Classical Athens, such as education, health, as well as the full provision of public goods such as public buildings infrastructure and of course, defense. But due to space limitations we cannot reproduce this evidence here. Our purpose with this paper is to expand the findings of the above authors on four environmental goods and services that were provided as public goods in Classical Athens: collective hygiene, fertilizing techniques as a form of renewal energy resource and finally, waste management. To the best of our knowledge, this is the first time where such kind of research regarding Classical Athens is provided, from an *Environmental Economics* point of view.

3.1. *Personal hygiene provided as a public good: The balaneia and the gymnasia*

Ensuring a high level of hygiene should be considered among the top priorities for societies that are characterized by strong economies. Especially now, with the current Covid-19 global pandemic, hygiene is of top priority in the agenda of politicians, policymakers, scientists and physicians specializing in epidemiology as a critical and successful precautionary measure to face the global pandemic. Of course hygiene is strongly related to having easy and regular access to bathroom infrastructure. Bathing, as a primary form of hygiene played a critical role in the lives of the Ancient Greeks as a whole, as attested by the archaeological findings regarding the construction of numerous bath buildings as well as frequent commentary on the baths by ancient authors from Homer onwards. This was true both at the level of personal hygiene and at the public level.

At the level of personal hygiene, the median house in Classical Athens had a bath. According to Gill (2008, 208-209) the earliest references to baths and bathing in Greece date to the 8th century BCE when Homer refers to the bathing of Homeric heroes in single tubs. Tubs have been found even in earlier periods, at Knossos, Mycenae, and Pylos during the Mycenaean Age period (1600-1100 BCE) which denotes that private bathing was an established social behaviour already existing at even much earlier times. References by Homer to hot baths appear in various passages in both the *Iliad* and the *Odyssey*.

In Athens as well as other Greek city-states during the Classical period, most of the houses had a bathroom with a small bathtub with a seat. But what is also very important is that the state also run public baths under a provision of a public good logic so as to secure the collective hygiene of citizens. In particular, those citizens and *metics* (alien residents, mostly Greeks from other city-states staying in Athens for work purposes) who did not enjoy a privilege of having a bath tub in their homes, from the 4th c. BCE could resort to public baths known as *balaneia*. Travlos (1971) who made a detailed study regarding the architectural constructions in Classical Athens and Gill (2008, 209-210) argues that by the mid–5th century BCE the *balaneion* (in singular), or Greek public bath, was well-established in Athens. Bresson (2007) adds that any citizen or a *metic* could take a comfortable bath with hot water for a small fee (Bresson 2007). Thus, due to the very small price, the *balaneia* services should essentially be seen as a public good where, in reality, the Athenian state bore the substantial and the major part of the cost of operating these public infrastructures. The earliest of these urban baths dates to the mid-5th century BCE and is located outside the gate of Dipylon in the Kerameikos of Athens. In general, Greek baths can be found throughout the Mediterranean. They have been found at Olympia, Isthmia, Delphi, Nemea, Corinth, Athens, Delos, Epidaurus, Messene and Olynthus and several other places in mainland Greece and elsewhere. They can also be found, among others, in Alexandria (Egypt) and Syracuse (South Italy).

Image 2. A *balaneion* at the Dipylon gate in Athens

Source: Travlos (1971: 182).

According to Gill (2008: 209) the location of the Kerameikos bath outside the city walls on the west side of the road leading to the Academy suggests that this urban bath served both private and social purposes and was frequently used by a diverse clientele entering Athens through the Dipylon gate coming from the port of Piraeus. The fact that public baths were often located outside the walls of a city, examples of which can be seen in Athens, Piraeus, Eretria, and Eleusis, denotes that this practice was not unusual for the period. We assume that the Athenians had created enough baths on the outskirts of the city for anyone entering the city, whether a citizen, *metic* or a foreigner, to reduce the risk of epidemics. Therefore, before the famous baths of Rome, public baths existed in the Greek city-states too, as described by authors such as Pseudo-Xenophon (*Constitution of the Athenians* 2.10). The *balaneia* were further expanded during the Hellenistic period (322-146 BCE) in Asia Minor and the Eastern societies due to the control of these areas by the Greeks under Alexander the Great.
Under the same logic with the public baths, the so-called *gymnasia* functioned. They were large athletic facilities which also provided baths, similar in philosophy to a modern fitness center. There were three public *gymnasia* (Academy, Lyceum, Cynosarges) where access was free to every free citizen or *metic* for taking a comfortable bath with hot water regardless of income and social class (Fisher 1998).
As a final comment, there is no doubt that the *balaneia* were also related to geothermal energy, which is a form of a renewable energy under modern standards This kind of energy was exploited by the Greeks as a mechanism for curing several body illnesses. Many thermal springs in the antiquity were exploited by the Greeks, and they are still being exploited nowadays for curative purposes, such as in Edipsos, in Methana, Pozar etc.

3.2. Collective hygiene as a public good: The koprologoi and the astynomoi

Regarding collective hygiene the Athenians had introduced laws that punished citizens who fouled the streets with waste and sewage that was produced in their homes. In particular, in every of the Athenian neighborhoods any waste from cesspits and latrines, produced in each household had to be stored in a particular pit which also functioned as a statutory dump, placed just outside each household (Owens 1983: 44, 47). The pits would then had to be emptied periodically and it was the owners' responsibility to ensure that this task was done, presumably by summoning the *koprologoi* a service being responsible for the collection and removal of sewage and the cleaning of the streets. Furthermore, defecating in the streets and in the Agora (the main Athenian marketplace) was severely punished with a fine imposed to

them by the *astynomoi* (see below) (Owens 1983: 46). Essentially, the *koprologoi* were cesspool/sewage pickers who were responsible to empty the cesspools in each of the 139 municipalities of Athens (Lindenlauf 2004: 94).

There is no doubt that the Athenians imposed fines to the citizens or *metics* who polluted the streets because they had understood that non-compliance to hygiene measures, if becoming intense, could harm the collective hygiene not only in the microcosm of each separate neighborhood or a *deme* (municipality) but also in the society as a whole.[6] In a modern interpretation, the Athenians wanted to neutralize any kind of improper behaviour of citizens that could cause *negative externalities* (in environmental terms) in the society as a whole (under a Pigouvian logic).

The supervision of the cleanliness of the streets and the hygiene (environmental) behavior of citizens as a whole was assigned to a public service known as the *Ten Astynomoi*, each one originating from the ten Athenian tribes. They were elected by the Assembly of citizens for an annual year service. Half of them served in the city of Athens and the rest in the port of Piraeus. They had various duties regarding the cleanliness and maintain order on the streets. They among others, oversaw road maintenance and that the rubbish and dung collectors, that is, the *koprologoi*, did not drop their dung within ten *stadia* (approximately 1,85 kilometers) of the city wall (Cox 2007: 770). This means that the garbage was collected in a specific waste collection area which served as a place for collecting the total garbage of the city. Thus, in all probability, the Athenians were the first or one of the first societies ever where a waste management policy was implemented.

By both the ancient sources and their modern interpretations it is not absolutely clear if the *koprologoi* were either Athenian citizens who worked as private scavengers or public slaves instead, who acted as public sweepers under the direct supervision of the *astynomoi* (Cox 2007). However Owens (1983), Lindenlauf (2004) and Ault (2007, 263) persuasively argue that the *koprologoi* were in fact private scavengers. In other words, this shows a public-private partnership (*3P*) form for the provision of a public good where the state outsources the private scavengers the cleanliness of the city essentially in the form of an agreement, which in the present era we could characterize as a *3P* form of a public work c. *3P* practices are very well-known nowadays. They consist cooperative institutional arrangements between public and private sector actors where private organizations are committed to the delivery of various public services (Hodge and Greve 2007). This *3P* environmental cooperation procedure of the Athenians was not something unusual since the Athenians implemented *3P's* in other cases too, such as tax collection through tax-farming, exploitation of the silver mines, the ship-building of warships known as *trierarchy* etc. Bitros et al. (2020) among others, provide extensive evidence on this.

As a final comment, Bresson (2007), an eminent historian on the economic organization regarding the Greek antiquity, praises the system of personal hygiene of the Greeks to the point of arguing that the ordinary citizen of an ordinary Greek city would be able to give hygiene and cleanliness lessons to King Louis XIV of France and his court (17th AD). Bresson's view contradicts directly with Garland (1998) who describes hygiene conditions in Classical Athens almost as awful by wrongly arguing, for example, that due to the non-existence of an authority for cleaning the streets, garbage piled up on the streets in huge quantities, creating a terrible stench and posing a serious health hazard, especially during the summer months. But Garland does not provide any further evidence as to why he reached to such an unjustified view.

3.3. Fertilizer as a primitive form of a renewable energy resource

Another important aspect regarding the institution of *koprologoi* is that it can be linked to what we nowadays characterize as recycling and renewable energy resources practices. Nowadays the following categories are considered as renewable resources: solar energy, wind energy, hydro energy, tidal energy,

[6] The city-state of Athens was organized into 139 separate *demes* (municipalities) where free citizens, *metics*, slaves and their families were living in out of a population of 250-300,000 inhabitants for the 5th century (Thorley 1996, 74) and 270,000 to 300,000 inhabitants for the 4th century (Hansen 1999: 93-94).

geothermal energy and biomass energy. What we will describe here, we think that it is more closely related to the biomass.

In particular, from literary sources we know that the *koprologoi* were able to reach profit by recycling and selling waste materials, mainly the dung of the animals (known as *kopros* or *kopron(es)*) that was collected by them in the streets of Athens, then recycled and then sold as a fertilizer. In fact, this was a very profitable activity for them (Ault 2007, 263). This was a practice that was taking place not only in Athens but also in many other city-states of the time such as Larissa, Olynthus and the island of Thasos among others. Ault (1994: 198-199) characteristically writes that:

> 'When domestic *kopros*, was supplemented with débris from the fields: fallow crops, brush, weeds, prunings, and the manure of grazing animals, a plentiful and powerful source of fertilizer was available. That the *kopron*, then, should be viewed not as a lowly garbage pit, but as a profitable compost heap or mulch pile is the next point of récognition'.

This description is related to one of the first (or perhaps the first ever) recycling processes in recorded history and to one of the first (or perhaps the first ever) waste management policies. Waste was collected under a *3P* method of cooperation as described above instead of the collection procedure to be only a matter of personal responsibility of each Athenian household separately.

As a general comment in this Section our findings denote that an important aspect regarding the success of environmental policy measures is related to environmental awareness. And obviously this is further related to a cultivation of environmental education in advance so that an environmental package of values actually becomes a way of life of the citizens through common set of environmental rules, habits, norms and protocols of behavior, as argued in the Introduction by citing various authors.

Regarding the development of such an awareness in Classical Athens, evidence can be found in the writings of ancient philosophers such as Strabo, Xenophon, Thucydides, Plato and others, who all recognized and warned the policymakers of their times about the side-effects that degradation of the land could have both for the present and future societies. To retrieve here all the evidence from the ancient sources regarding the ecological view of Ancient Greek philosophers, it could exceed the purpose of our analysis. The readers can consult authors such as Stone (2018) regarding this. Here we refer only to Plato in *Critias* (111) provides a description of how (what we nowadays characterize as) an ecosystem should thrive and prosper. Furthermore, we reproduce Aristotle in *Nicomachean Ethics* (1103a) who writes that:

> 'Neither by nature, then, nor contrary to nature do the virtues arise in us; rather we are adapted by nature to receive them, and are made perfect by habit'

This is actually an observation that can also be seen as a warning, since it implies that our lives are related to nature and that we must respect the environment in parallel to our daily activities.

But since the level of a society's environmental awareness is related to the mixture of institutions it has introduced for this purpose, we choose to finish with two more Athenian state institutions, related to environmental protection, at least to some extent. Here we refer on the *agoranomoi* and *hyloroi*. In principle the *agoranomoi* was an institution whose members were assigned with very serious duties, the main one being the supervision the Athenian market against profiteering practices that could harm its proper functioning (Bitros et al. 2020; Economou et al. 2021a,b; Halkos et al. 2021). Hughes (1982: 72, 2017) based on Aristotle's *Politics* in verses 6.5.4(1321b) and 7.11.4(1331b) argues that in many ancient city-states including Athens of course, governments supervised the protection of forests and watersheds and this was a widespread practice. Hughes (1982, 2017) further refers to the *agoranomoi* as environmental supervisors.

This attitude towards nature protection involved also regulations in areas such as forest products trade, the timber harvested, and the use of land, as well as the construction of public works to provide and control water supply and drainage. Responsibility for these matters was delegated to certain government

officials; in some cities, for example, forestland in the countryside was supervised by *hyloroi* (custodians of forests) who, Aristotle writes that had guard-posts and mess-rooms for patrol duty. Due to space limitations we cannot retrieve all this evidence here but a detailed source on the topic is provided by authors such as Thommen (2012) and Hughes (2017).

4. Concluding remarks

This paper is an attempt to link some of the economic aspects that are related to the function of the Athenian economy in Classical times, to a series of environmental issues through their historical diastasis. With this paper we described, in a connective way five environmental issues: i) hygiene measures both as a personal and a collective behavioural procedure ii) hygiene environmental auditing institutions, such as (mainly) the *koprologoi* and the *astynomoi*, as well as the supportive institutions such as the *agoranomoi* and *hyloroi*. iii) we also raised the issue of geothermal energy regarding the bathing techniques as introduced in Ancient Greece iv) we further referred on a fertilizing technique and recycling practices as a form of renewable energy practice v) waste management policy.

Of course, there is no doubt that these institutions, from their environmental perspective, need to be further analyzed and examined. Due to space limitations in this essay, we cannot extensively analyze the above institutions in more detail. However, we do hope that our paper provides an impetus for further research in this area that connects environmental issues to historical political economy.

Thus, with the above analysis regarding the Athenian Democracy as a case study, we believe that we have explained quite convincingly that this dual relationship has an intertemporal character.

We believe and we do hope that our paper will provide the impetus for a further focusing on environmental economics issues through the prism of methodological approaches that are linked to economic analysis and history. We promise a game theory analysis which links environmental issues with the Athenian institutions as analyzed above, in a research in the near future.

Bibliography

Acemoglu, D., Robinson, J., (2013), *Why Nations Fail*, New York: Crown Business.

Asilsoy, B., Oktay, D., (2018). Exploring environmental behaviour as the major determinant of ecological citizenship, *Sustainable Cities and Society*, 39, 765–771.

Amemiya, T. (2007). *Economy and economics of ancient Greece*. New York and Abingdon: Routledge.

Aristotle, (1934), *Nicomachean Ethics*, Aristotle in 23 Volumes, Vol. 19, Engl. Trnsl. H. Rackham, Cambridge, MA: Harvard University Press; London: William Heinemann Ltd. Perseus Digital Library.

Aristotle, (1944), *Politics*, vol. 21, Engl. Trnsl. H. Rackham, Cambridge, MA: Harvard University Press; London: William Heinemann Ltd. Perseus Digital Library.

Ault B. A. (1994), 'Koprones and oil presses : domestic installations related to agricultural productivity and processing at classical Halieis', in: *Structures rurales et sociétés Antiques. Actes du colloque de Corfou (14-16 mai 1992)*. Besançon : Université de Franche-Comté, pp. 197-206.

Ault, B. A., (2007), 'Oikos and Oikonomia: Greek houses, households and the domestic economy,' *British School at Athens Studies*, 15, 259-265.

Bitros, G. C., Karayiannis, A., (2008). Values and institutions as determinants of entrepreneurship in ancient Athens, *Journal of Institutional Economics* 4, 205–230.

Bitros, G.C., Economou, E.M.L. & Kyriazis, N.C. (2020). *Democracy and money: Lessons for today from Athens in Classical Times*. London and New York: Routledge.

Bresson, A., (2007), *L'Économie de la Grèce des Cites. Les Structures et La Production*, vol. 1. Paris: Armand-Colin.

Bresson, A. (2016a). *The making of the ancient Greek economy: Institutions, markets, and growth in the city-states*. Princeton, NJ: Princeton University Press.

Bresson, A. (2016b), "Aristotle and foreign trade,". E. M. Harris, in in Harris, E. M., Lewis, D. M., Woolmer, M., (Eds.) *The Ancient Greek economy: Markets, Households and City States* (pp. 41-65). New York: Cambridge University Press.

Cartledge, P. (2016), *Democracy: A life*. Oxford: Oxford University Press.

Cohen, E. E. (1992), *Athenian economy and society: A banking perspective*. Princeton: Princeton University Press.

Cox, C. A., (2007), 'The 'Astynomoi', private wills and street activity,' *The Classical Quarterly, New Series*, 57(2), 769-775.

Economou, E. M. & Kyriazis, N. (2017). The emergence and the evolution of property rights in ancient Greece, *Journal of Institutional Economics*, 13(1): 53–77.

Economou, E. M. & Kyriazis, N. (2019). *Democracy and Economy. An inseparable relationship from Ancient Times to today*. Newcastle upon Tyne. Cambridge Scholars Publishing.

Economou, E.M.L., Kyriazis, N.C. & Kyriazis, N.A (2021a). Money decentralization under direct democracy procedures. The case of Classical Athens, *Journal of Risk and Financial Management*, 14(1), 30.

Economou, E.M.L., Kyriazis, N.C. & Kyriazis, N.A (2021b). Managing financial risk while performing international commercial transactions. Intertemporal lessons from Athens in Classical times, *Journal of Risk and Financial Management*. 14: 509.

Fabi, V., Di Nicoli, M.V., Spigliantini, G., Corgnati, S.P., 2017. Insights on pro-environmental behavior towards post-carbon society, *Energy Procedia*, 134, 462–469.

Figueira, T. J. (1998). *The power of money: coinage and politics in the Athenian Empire*. Philadelphia: University of Pennsylvania Press.

Finley, M. I. (1973). *The ancient economy*. Berkeley: University of California Press.

Finley, M. I. (1983). *Economy and society in Ancient Greece*. New York: Penguin Non Classics.

Fisher, N. (1998), 'Gymnasia and the democratic values of leisure,' in P. Cartledge, P. Millett, S. von Reden (eds.), *Kosmos: Essays in Order, Conflict and Community in Classical Athens*, Cambridge: Cambridge University Press, 84-104.

Garland, R. (1998), *Daily Life of the Ancient Greeks*, Westport, Connecticut and London: Greenwood Press.

Gkargkavouzi, A., Halkos G.E., & Matsiori, S. (2019). Environmental behavior in a private-sphere context: Integrating theories of planned behavior and value belief norm, self-identity and habit, Resources, *Conservation and Recycling*, 148, 145-156.

Gill, A., (2008), "Chattering" in the Baths: The Urban Greek Bathing Establishment and Social Discourse in Classical Antiquity, Proceedings of the 36th International Conference, Budapest, April 2-6, 2008. Retrieved at: https://proceedings.caaconference.org/files/2008/CD27_Gill_CAA2008.pdf

Halkos G. & Kyriazis, N. (2010). The Athenian economy in the age of Demosthenes, *European Journal of Law and Economics*, 29: 255–277.

Halkos G. (2011), Environmental pollution and economic development: Explaining the existence of an environmental Kuznets curve, *Journal of Applied Economic Sciences*, *Journal of Applied Economic Sciences*, 6(2): 144-167.

Halkos G. & Managi, S. (2016). Measuring the Effect of Economic Growth on Countries' Environmental Efficiency: A Conditional Directional Distance Function Approach, *Environmental & Resource Economics*, 68(3): 753-775.

Halkos, G., Kyriazis, N. & Economou, E.M.L. (2021), Plato as a Game Theorist towards an International Trade Policy, *Journal of Risk and Financial Management*, 14: 115. https://doi.org/10.3390/jrfm14030115

Hansen, M. H., (1999), *The Athenian Democracy in the Age of Demosthenes*, London: Bristol Classical Press.

Harris, E. M. & Lewis, D.M. (2016), "Introduction: Markets in Classical and Hellenistic Greece," in Harris, E. M., Lewis, D. M., Woolmer, M., (Eds), *The Ancient Greek Economy: Markets, Households and City States* (pp. 1-40). New York: Cambridge University Press.

Hodge, G. A. & Greve, C. (2007), Public–Private Partnerships: An International Performance Review, *Public Administration Review*, 67(3), 545–558.
Hodgson, G. M. (2015). *Conceptualizing capitalism: institutions, evolution, future*. Chicago: University of Chicago Press.
Hughes, .J. D. (2017). *Environmental Problems of the Greeks and Romans: Ecology in the Ancient Mediterranean*. Baltimore, Maryland: Johns Hopkins University Press.
Lindelauf, A., (2004), 'Dirt, cleanliness and social structure in ancient Greece,' in A. Gardner (ed.), Agency Uncovered: Archaeological Perspectives on Social Agency, Power and Being Human, London: UCL Press, 81-104.
Nelson, R.R. & Winter, S.G. (1982), *An evolutionary theory of economic change*. Cambridge, Massachusetts: Harvard University Press, Belknap Press.
North, D.C. (1981), *Structure and Change in Economic History*, New York: W.W. Norton and Company.
North, D.C. (1990), *Institutions, Institutional Change and Economic Performance*, Cambridge: Cambridge University Press.
Ober, J. (2008). *Democracy and knowledge. Innovation and learning in Classical Athens*. Princeton University Press: Princeton.
Owens, E. J., (1983), The koprologoi at Athens in the fifth and fourth centuries, *The Classical Quarterly*, 33(1), 44-50.
Peretz, J., Bohm, R., & Jasienczyk, P. (1997). Environmental Policy and the Reduction of Hazardous Waste, *Journal of Policy Analysis and Management*, 16(4), 556-574.
Plato, (1925), *Critias*, Plato in Twelve Volumes, Vol. 9, Engl. Trnsl W.R.M. Lamb, Cambridge, MA, Harvard University Press; London, William Heinemann Ltd. . Perseus Digital Library.
Pseudo-Xenophon, (1984), Constitution of the Athenians, Engl. Trnsl. E. C. Marchant, Cambridge, MA: Harvard University Press; London: William Heinemann, Ltd. Perseus Digital Library.
Schenkel, W. (1993). Waste minimization and waste recycling as an important issue in environmental protection, and the limits of this strategy*, Ekistics*, 60(358/359), 8-13.
Shinkuma, T. & Managi, S. (2011), *Waste and Recycling: Theory and Empirics* (Routledge Studies in Ecological Economics). London and New York: Routledge.
Smulders, S., Toman, M., & Withagen, C. (2014). Growth theory and 'green growth, *Oxford Review of Economic Policy*, 30(3), 423-446.
Stone, M. (2018). Plato, Environmental Sustainability, and Social Justice, Athens Journal of Humanities & Arts, 5(1): 105-118.
Thommen, L. (2012). *An environmental history of Ancient Greece and Rome*. Cambridge: Cambridge University Press.
Thorley, J., (1996), *Athenian Democracy*, London and New York: Routledge.
Woolmer, M. (2016). "Forging links between regions: Trade policy in classical Athens," in Harris, E. M., Lewis, D. M., Woolmer, M., (Eds.), *The Ancient Greek Economy: Markets, Households and City States* (pp. 66-89). New York: Cambridge University Press.

Spillovers, Technological Hierarchies, and the environmental effects through clean technologies adoption

Nikos Chatzistamoulou[1,2], Kostas Kounetas[2]
[1] *Department of Economics, University of Ioannina, Greece*
[2] *Department of Economics, University of Patras, Greece*
chatzist@upatras.gr, kounetas@upatras.gr

Abstract
In this paper we explore the nature of spillover effects and their impact on learning through a multihierarchy framework of production frontiers on a global scale for a nine-year period, based on the development level of each country economy. Under a non-parametric metafrontier framework and through the Data Envelopment Analysis under variable returns to scale, we explore the effect of spillovers and the impact of clean technologies adoption on performance change. Econometric results indicate that performance differentials between countries of different development level may be attributed to absorptive capacity, foreign direct investments and knowledge flows circulating in each learning grid. A moderation effect of absorptive capacity is present, however not in a particularly systematic way. Moreover, the adoption of clean technologies seems to be a game-changer in improving performance growth.

Keywords: Data Envelopment Analysis, Technological Hierarchies, Knowledge flows, Clean Technologies.

JEL Codes: O44;D2;P18;C50;C60.

Two stage DEA and environmental elasticities of polluting DMUs

George Halkos[1] & Christina Bampatsou[1, 2]

[1] *Laboratory of Operations Research, Department of Economics, University of Thessaly, 78 October 28th Str, 38333, Volos, Greece*

[2] *Department of Regional Development, Faculty of Economic Sciences, Ionian University, Filosofon & Tzeveleki, 31100, Lefkada, Greece*

halkos@uth.gr, c.bampatsou@gmail.com

Abstract

The present study looks into DEA bootstrap approach combined with long - run elasticities and marginal effects to both efficiency and economic growth index with respect to environmental variables. The methodology applied provides a useful and informative approach to tracking decarbonisation of energy -related GHG emissions systems. The purpose of this study was to analyze the rates of change taking place in the energy systems of polluting countries, in the light of the climate change mitigation objectives, from Paris agreement to Glasgow climate pact and therefore to enhance policy coherence for sustainable development by establishing best practices for resource management techniques.

Keywords: Two stage DEA, Efficiency, GHG, Environmental Variables, Elasticities, Marginal effects, Decarbonisation, Paris agreement, Glasgow climate pact

JEL Codes: O11; O57; Q01; Q40; Q43; Q48; Q50; Q58; R15.

A multi-criteria methodology for off-grid small settlements

Evangelos Tsiaras & Frank A. Coutelieris
Department of Environmental Engineering, University of Patras, Agrinio
etsiaras@upatras.gr, fcoutelieris@upatras.gr

Abstract
Renewable Energy Systems has enormous potential to meet most of the world's energy demands. Precisely, RES-based hybrid power plants seem to be a promising option towards elimination of environmental impact of production and consumption of electricity. A multi-criteria methodology for identifying the most appropriate location(s) for installing low-scale RES-based hybrid electricity production systems to cover local energy demands without grid connection is presented here. The selection is initially based on geographical, spatial and demographical data, while also taken into account are optimally combined meteorological data (solar and wind potential), with available resources (in terms of free space, land use and investment costs). In order to assure high possibility of full load coverage by RES, we have chosen settlements presenting low electricity demands, located at areas of high and low solar and wind potential and maintain low population range (50 - 100 residents). The selected settlements are Repetista and Areti, villages at Kalpaki, Ioannina, Epirus, Hagia Sophia and Fisini, villages at Lemnos Island, North Aegean Sea, Kumasa and Kandyllas, villages at Vagonia, Heraklion, Crete and Kato Lefkos and Lefkos, Karpathos Island, Dodecanese, South Aegean Sea. The desired loads are crucial for the optimal operation of the off-grid power production systems. On top of that, optimization in not only the size and the operation of the hybrid system, but also in the composition of energy sources mixture, is also performed. Findings show that it is feasible to implement autonomous power generation and electricity coverage from renewable energy systems for small settlements, based on the presented multi-criteria methodology. Finally, the social acceptance for such an installation is presented after using and elaborating a relative questionnaire that was answered by the residents of two settlements.

Keywords: Methodology, Off-grid power production, Renewable, Social acceptance, Energy
JEL Codes: Q20;Q42;Q43;Q47;Q55;Q56.

1. Introduction

The combination of RES technologies into hybrid systems could result in addressing several problems the planet is facing regarding energy. Electricity demands constantly increase (approximately doubled within last ten years) while the limitation of fossil deposits underlying the need for alternative energy production (Olabi, 2013). While renewable technology becomes more and more mature with the years, hybrid systems have recently become feasible alternatives that satisfy the requirements for electricity production with environmental protection (Rathore & Panwar, 2007). Given the environmental potential for a specific location, a hybrid energy system combined with an energy storage system is an interesting option to cover relatively low electrical loads in remote areas (Ansong et al., 2017; Boute, 2016; Forde, 2017; Sandwell et al., 2016) where either there is no utility for power supply or it is difficult and cost-ineffective to attain a continuous interconnection to the existing grid. Stand alone and hybrid photovoltaic/wind systems seem to be a very promising option with excellent prospects to cover the energy needs of specific areas in an efficient and sustainable way. On the other hand, the widely accepted practice is the installation of pv/wind farms that provide electricity directly to the local grid. This option simply offers an amount of clear energy to the energetic mixture, which cannot be considered as "totally clear". This aim might be satisfied through the decentralization of power production which could be produced in situ by using RES (Financial Times, 2020a). The main issue here is the phase matching of RES-potential availability, i.e. the RES-based electricity production, with the consumers' needs. This matching is a scale-dependent function which is still an open research topic, without a globally accepted "total solution".

Following this theoretical approach, this work will study four different regions and eight different settlements of Greece and try to determine the best possible combination of RES technologies for the construction of a stand-alone hybrid RES system in two small villages of each region. This simulation will be based on local meteorological, demographical, energy-consumption and social data and should provide the most profitable and efficient scenario for electricity production. The energy demands of each village are calculated in detail by using specific typical loads that have to be covered for each house, country house or small business found in the area. Also the population of each village is taken into consideration, as well as the number of buildings and the annual use or not of each one of them. After calculating the annual load of each village depending on that and using real-life meteorological data of wind speed and solar radiation, an optimal off-grid scenario will be presented in each village regarding the best possible energy coverage of every month. This will be followed by the cost of the off-grid scenario and the impacts on the environment and society of each village. Finally, the social acceptance of residents is presented in case of installing an autonomous hybrid system with the compilation and distribution of a questionnaire that was answered by the residents of the two settlements of Epirus.

2. Theory

2.1 Methodology

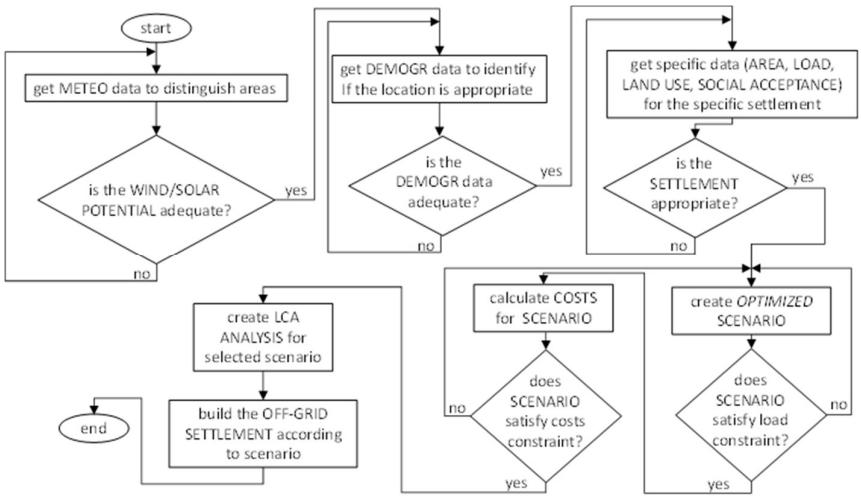
Our methodology for area selection is based on the following data: Solar radiation, wind potential, demographic data, geographical and geospatial details as well as land use.

Solar radiation: Greece has a particularly high solar potential compared to the northern European countries. Average annual solar radiation in the horizontal plane varies from 1400 - 1500 kWh/m^2 in Northern Greece to 1800 - 1900 kWh/m^2 in the southern Peloponnese, Crete and the Dodecanese (Nikitidou et al, 2015). The selection of settlements was based on the incident solar radiation. The average solar radiation measured in Greece, i.e. from the lowest price of 1400 kWh/m^2 to the highest value of 1900 kWh/m^2, is 1650 kWh/m^2. This value is very close to that of 1600 kWh/m^2 calculated by Lalas et al. (1983). We also distinguish the areas of interest into two categories: those below 1600 kWh/m^2 ("low-solar potential areas") and those above 1600 kWh/m^2 ("high-solar potential areas").

Wind potential: Greece is often characterized as one of Europe's most windy areas. The seasonal variations in atmospheric pressures combined with the development of local winds, are the main determinants of wind conditions in the country (Nastos et al, 2002). Wind potential in Greece ranges

from 0 m/sec to over 10 m/sec (Centre for Renewable Energy Sources, CRES, http://www.cres.gr). Based on this range, the average value is 5 m/sec. We have again separate the areas into two categories: those below the average wind potential ("low wind potential areas") and those located above the average wind potential ("high wind potential areas").
We also make use demographical, geographical, geospatial and land use data to support our methodology. Population was in a range of approx. 50 to 100 inhabitants in order to assure quite low loads along with relatively low-cost installation with low area coverage. For the sake of clarity, the following Fig, 1 depicts the algorithm used, in a flowchart (Tsiaras et al, 2020).

Fig. 1: Schematic representation of the methodology applied.



2.2 Electric load criteria

An on-site survey has been carried out to record the number of buildings at each settlement as well as their status (home, country house, small enterprise, public-use building). To identify the averaged load per building during a six-year period, it is necessary to find out the number and the energy class of electrical devices used, thus actual electrical charges can be recorded on a monthly basis. As far as the majority of enterprises concerned is in the tourism sector, the peaks of the electrical loads are encountered during summer months as well as some weekends of the year. Finally, public buildings in these settlements are not used for most of the time.
We have estimated the consumption of the electrical appliances of the eight settlements making some assumptions. These assumptions are:

- Non-residents have all appliances closed except from refrigerators and freezers.
- The non-permanent inhabitants stayed on an average of one month in the winter and two months in the summer.
- Closed homes do not consume electricity.
- Municipal bulbs operate on average 12 hours in the winter and 10 hours in the summer.

2.3 Social acceptance

An important part of this survey concerns the social acceptance of wide use of RES, which is largely overlooked due to growing public concerns about depletion of natural resources and environmental issues associated with conventional fossil fuels (Wuestenhagen et al, 2007). It is obvious that the reaction of society can prevent or delay these projects. However, the social acceptance issue emerged as the citizens became more aware of advantages and disadvantages of renewable energy technologies and

this has led, in some areas, in social rejection of renewable energy development (Ribeiro et al., 2011; Sheinbaum-Pardo et al., 2012)

In general, residents should be properly informed about the autonomous hybrid photovoltaic-wind turbine system prior to installation. An accurate way to inform them with measurable results is to use a questionnaire for the inhabitants of small settlements with the help of local community. A sample of this questionnaire is presented in Tables 1a & 1b. The questionnaire's questions had the rationale of reducing the energy efficiency in the selected settlements and the answers were collected to a large extent by the face-to-face method and to a lesser extent by telephone communication. The selected results may strongly affect the decision making process.

Table 1a: Questionnaire of the 1st settlement

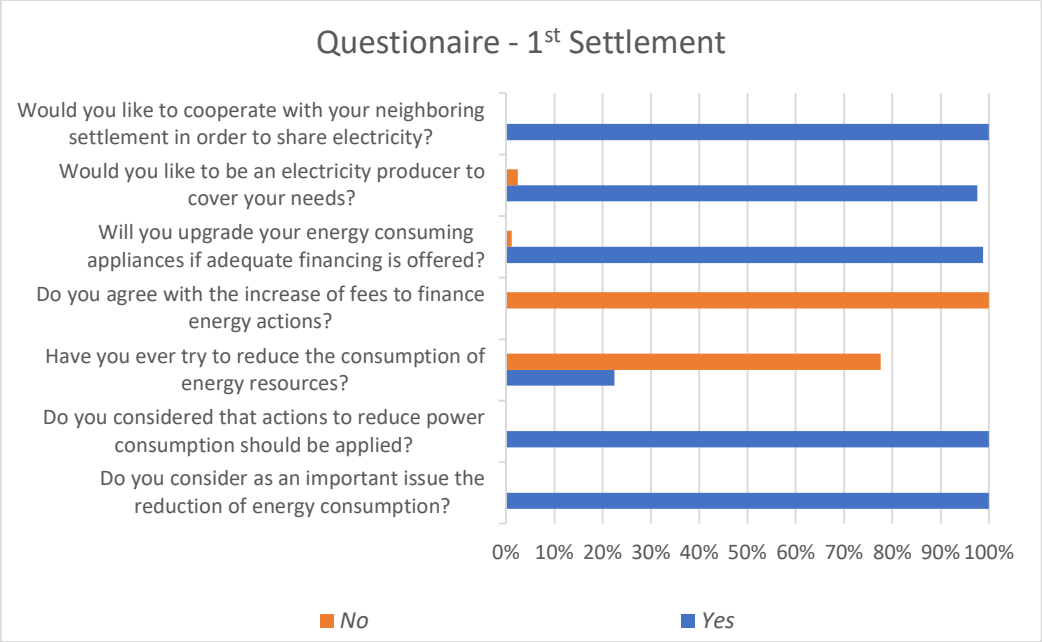
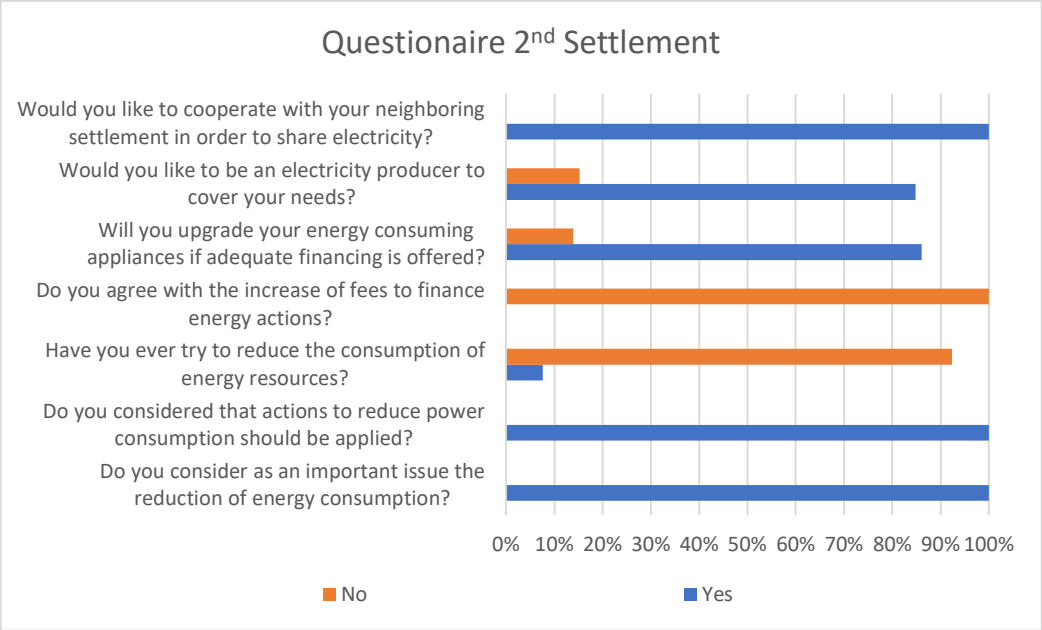


Table 1b: Questionnaire of the 2nd settlement



3. Result and discussion

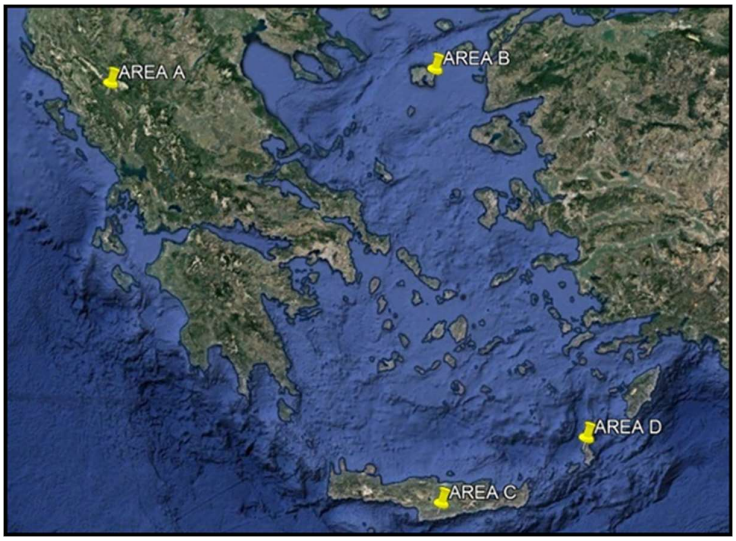
The methodology has been applied to design a standalone (off - grid) hybrid wind turbine - photovoltaic system with battery storage for small-scale settlements. Following the above-presented criteria, the selected areas (Fig. 2) are as follows:

- Low solar and low wind potential (AREA A): Repetista and Areti, villages at Kalpaki, Ioannina, Epirus,
- Low solar and high wind potential (AREA B): Hagia Sophia and Fisini, vilages at Lemnos island, North Aegean Sea,
- High solar and low wind potential (AREA C): Kumasas and Kandyllas, villages at Vagonia, Heraklion, Crete
- High solar and high wind potential (AREA D): Kato Lefkos and Lefkos, Karpathos island, Dodecanese, South Aegean Sea.

The selection of areas came out through the satisfaction of the following criteria:

- The areas should be far away from urban centers,
- The areas must be of low touristic impact to avoid singularities in demands' increment during the summer months,
- The distance between the selected settlements could be three kilometers (max.) to help interconnection,
- The population should be approx. 50 to 100 residents,
- A meteorological station measuring solar radiation and wind speed is absolutely necessary, even if located in a third nearby settlement which does not interfere with an obstacle (i.e. mountain) between them.

Fig. 2: The four selected Greek areas.



The study of the installation of the hybrid power generation system begun with the analytical study of the eight villages which is presented in Table 2.

Table 2: Analysis of the eight settlements

Settlements	Houses	Enterprises	Public Buildings	Solar Radiation (Kwh/m^2)	Wind speed (m/s)	Max. Temp (ºC)	Min. Temp (ºC)
Repetista	83	2	2	1508,9	1,3	23	8,5
Areti	78	2	2	1508,9	1,3	23	8,5
H. Sofia	78	1	2	1591,2	4,5	19,2	14,7
Fisini	102	0	2	1591,2	4,5	19,2	14,7
Koumasa	44	1	1	1803,8	3,6	18	17,8
Kandylas	35	1	1	1803,8	3,6	18	17,8
K. Lefkos	45	17	0	1824,7	5,1	19,2	19,1
Lefkos	40	3	0	1824,7	5,1	19,2	19,1

The required solar and wind data, as well as the maximum and minimum temperature values have been recorded by nearby meteorological stations. There is a wide range of meteorological data available (from June 2008 till December 2018) and the proximity of meteorological station ensures high accuracy of the measurements. Solar data are recorded every five minutes, wind data every fifteen minutes and temperatures once per day.

Because there is a need to fully cover - 24hour power supply - the settlements with electricity, the appropriate scenario is the "Off-grid scenario" which assures a continuous 24hour power supply for all settlements to fully cover the desired loads. This scenario is based on other factors such as the cost of installing the hybrid system, annual maintenance costs and the cost of interconnection between settlements. In terms of energy, the environmental friendly viability of the system associated with the reduction of CO_2 emissions and system's power losses have been also considered for optimizing the operation of the hybrid system. As far as the selected settlements are quite isolated and their population is low and very mature, the need of a 24hour energy supply is essential. The optimal design of such a hybrid system should cover a steady electricity flow at the time its consumption, without allowing normal daily fluctuations of RES potential to affect power supply (Little et al., 2007). The same must

also stand for unfavorable weather conditions, especially in the winter months due to lack of sunlight as well as low wind potential. Constant electricity flow will be achieved by using batteries that will not only be used as a backup energy system but also as a replacement for the electricity distribution network (Abdullah et al., 2010).

3.1 Eight settlements' data

Before starting to build the hybrid system scenarios, we present the annual electrical consumption of the eight settlements provided by the Greek Power Company.

Table 3: Settlements' electrical consumption (kwh/year) - (Greek Power Company)

	2012	2013	2014	2015	2016	2017
Repetista	150.981	133.712	141.927	118.434	118.474	132.331
Areti	131.721	124.723	120.451	126.068	135.824	140.331
Hagia Sofia	130.854	112.215	114.844	118.746	118.155	116.367
Fisini	149.174	127.925	130.922	135.370	134.696	132.658
Koumasa	264.762	305.627	203.293	355.651	348.392	313.163
Kandylas	100.868	88.492	66.451	99.516	114.859	101.014
Kato Lefkos	286.019	331.664	302.364	324.149	320.376	316.301
Lefkos	183.181	212.414	193.649	207.601	205.185	202.575

Using the data of Table 3, we notice that the settlement's consumption varies between 66.451 kwh/year to 355.651 kwh/year. We, then, calculate the average solar radiation (in horizontal global irradiance plane), wind and temperature values for each hour for an entire 24h period. Then, we performed the same procedure for all the days of the month and, finally, for all the months of a year. The results for the 24h yearly averaged values for solar and wind potential are presented in Table 4a and Table 4b for the eight settlements.

Table 4a: Annual solar radiation (wh/m^2) on a 24hour basis for the four areas

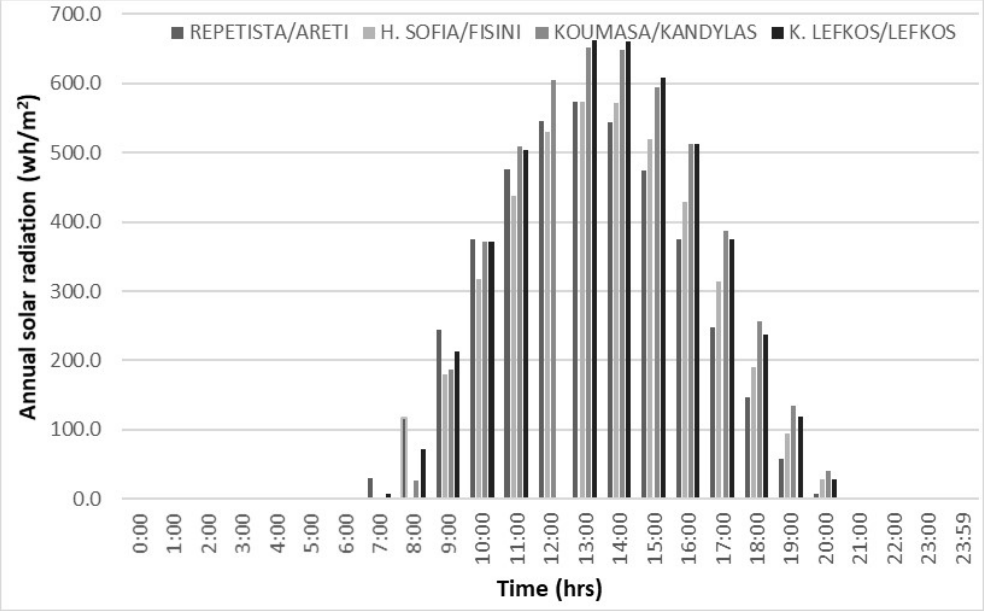
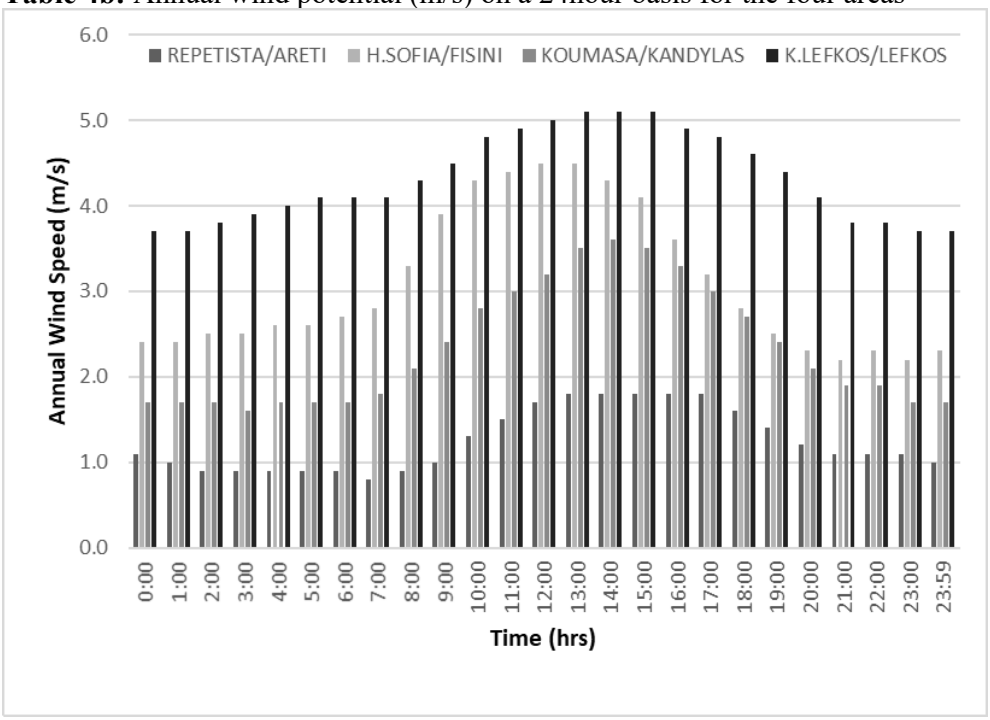


Table 4b: Annual wind potential (m/s) on a 24hour basis for the four areas



3.2 PV & Wind

For our solar radiation measurements, we considered a typical prototype, 275W polycrystalline photovoltaic panel, with dimensions 1.65m x 0.991m = 1.635m^2 and efficiency of 16.82%. We have chosen this one because of its cost and efficiency. For the wind speed measurements, we have worked in an analogous manner, considering a prototype a 50 kw wind turbine which operates in the range of 2.5 - 12 m/s wind speed with an efficiency of approx. 90%, including a permanent magnet 360 VAC/540 VDC generator without a gearbox and a noise level of 55 dBA at 40 m. The proposed wind turbine is a

three-bladed horizontal axis one. Its main components are the tower, the rotor, the nacelle, the generator and the turbine's base-ground.

3.3 Off-grid scenario

In Table 5 we present the results for the off-grid scenario when applied in the eight settlements. The energy produced exceeds the desirable needs for the majority of the months during a year, while for some others is marginal. These months are mainly those when the populations sharply increases due to visitors (mainly in summer holidays).

Table 5: Off-grid scenario for the selected settlements

	Repetista	Areti	H.Sofia	Fisini	Koumasa	Kandylas	Kato Lefkos	Lefkos
PV	4050	4050	2400	1575	4400	5000	1200	1008
WT	0	0	6	4	6	0	0	3
Total electricity produced (*kwh/year*)	371384,2	371571,5	771606	512214,5	868074,8	507974,5	71116,4	472987,4
Production of additional electricity (*kwh/year*)	220403,2	231240,5	640752	363040,5	512423,8	393115,5	-260547,6	260573,4

3.4 Total cost of the off-grid scenario

For the efficient and stable operation of the system, other parts are required such as, inverters, cables, batteries etc. Therefore, in order to accurately calculate the environmental performance of the system, these components must be included in the study. At the end of project life, the recycling option was selected, with efficiency 20% of the total component's mass. The rest of the mass is incinerated or landfilled. The project lifetime is considered to be 25 years while the lifetime of the specific components are different: the PVs and the WTs usually present lifetime longer than 25 years, thus there is no need for their replacement during the project. Normally, batteries have a lifespan of 4 years (7 replacements during project's lifetime), inverters have 10 years (3 replacements), chargers/controllers present 4.5 years (6 replacements) while the lifetime of cables is too long for any replacement. The inverter consists of various electronic components such as, transformers, connectors, resistors, capacitors etc. The studied inverter is a 120 VAC/60 Hz Sinewave, 3000 Watts, 24 V DC and 230 V of grid voltage. Since specific data are available data for 2,5 kW inverters, an extrapolation was carried out to obtain adaptation for the inverter of this work. The excess energy is stored in batteries and in the off-grid scenario, it seems that this energy could also be used on some cloudy or non-windy days without a problem. The batteries that are studied here are lead-acid (Pb) AGM-gel, deep cycle (C20 capacity) type, recommended for residential use. Each battery weights from 19 to 48 kg. The charge controller are also used to control charging therefore the lifespan of the batteries and the system's safety are increased. Finally, the studied charge controllers are assumed to be a MPPT 150/100. The total costs per area per settlements is presented in Table 6.

Table 6: Costs for the eight settlements

Areas	Settlements	Off-grid scenario (€)
Epirus	Repetista - Areti	2.875.793,62
Limnos	H.Sofia - Fisini	2.349.432,29
Crete	Koumasa - Kandylas	4.133.264,91
Karpathos	K.Lefkos - Lefkos	1.161.099,34

4. Comparison with the National network

To be able to successfully compare the costs of our system with those of a grid connected system, it was first calculated through the maximum consumption of our settlements, which was mentioned in Table 3, the cost in € for the payment of the electricity provider bills. The price of electricity supply is approximately 0.12 € per kWh. This price is about 46% of the total amount due to additional charges for the transmission system, for the distribution system, for the utilities services, other charges, special fee for reducing gaseous emissions, interest, stamps, Public TV, Municipality, etc. In this context the final total price is about € 0.25 / kWh. The amount that the settlements will be asked to pay for the whole project is shown in Table 7. Finally, in Table 8 we present the total differences in costs which comes from the subtraction of the off-grid scenario derived from Table 6 with the total costs (€)/project depicted on Table 7.

Table 7: Total electricity costs for the eight settlements

Areas	Max. consumption (kwh/year)	Cost (kwh)	Max. cost (€)/year	Project period (years)	Total cost (€)/project
Epirus	291.312	0,25	72.828,00	25	1.820.700
Limnos	280.028	0,25	70.007,00	25	1.750.175
Crete	470.510	0,25	117.627.50	25	2.940.688
Karpathos	544.078	0,25	136.019,50	25	3.400.488

Table 8: Total electricity costs differences for the eight settlements

Areas	Settlements	Total Difference (€)
Epirus	Repetista - Areti	1.055.093,62
Limnos	Hagia Sofia - Fisini	599.257,29
Crete	Koumasa - Kandylas	1.192.576,91
Karpathos	Kato Lefkos - Lefkos	- 2.239.388,66

It is rather clear that the most cost-effective scenario is the one applied in the area with high solar and high wind potential (Karpathos island). On the other hand, the results regarding costs in the other three areas will be further improved when the forthcoming reduction of the prices is also taken into account.

5. Conclusion

The methodology of identifying the most appropriate location(s) for the installation of autonomous RES-based hybrid energy systems with battery storage, has been developed in this work, especially for small-

scale settlements. Methodology was based on the combination of the local renewable's potential with availability and feasibility of the project. The main optimization constrain is the continuous 24X7 load coverage, despite the relatively high costs. Decrease of energy demands by applying well-known practices, use of environmental–friendly power production methods and adoption of the necessary social acceptance and cooperation will allow for a new perspective in energy distribution. This methodology also become a very important tool for energy policy makers, especially when work on small settlements.

References

Abdullah M.O., Yung V.C., Othman A.K., Hamid K.B.A., Tarawe J. (2010), Review and comparison study of hybrid diesel/hydro/fuel cell energy schemes for a rural ICT Telecenter, Energy, 35, 639 – 646

Ansong M, Mensah L.D, Adaramola S. (2017). Techno-economic analysis of a hybrid system to power a mine in an off-grid area in Ghana, Sustainable Energy Technologies and Assessments, 23, 48 – 56.

Boute A. (2016). Off-grid renewable energy in remote Arctic areas: An analysis of the Russian Far East, Renewable and Sustainable Energy Reviews, 59, 1029-1037.

Financial Times, (2020a). Global power grids decentralise towards a flexible future, by Middlehurst C., July 15, 2020.

Lalas D.P, Tselepidaki H, Theocharatos G. (1983). An analysis of wind power potential in Greece, Solar Energy, 30 (6), 497–505

Little M, Thomson M, Infield D. (2007). Electrical integration of renewable energy into stand-alone power supplies incorporating hydrogen storage, International journal of Hydrogen Energy, 32, 1582 – 1588.

Nastos P.T, Philandras C.M, RepapisC..C. (2002). Application of canonical analysis to air temperature and precipitation regimes over Greece, Fresen Environ. Bull, 11, 488 – 493.

Nikitidou E, Kazantzidis A, Tzoumanikas P, SalamalikisV,.Bais A.F. (2015). Retrieval of surface solar irradiance, based on satellite-derived cloud information in Greece, Energy, 90, 776 – 783.

Olabi A.G.(2013). State of the art on renewable and sustainable energy, Energy, 61, 2 – 5.

Rathore N.S, Panwar N.I. (2007), Renewable energy sources for sustainable development, New Delhi, India, New India Publishing Agency.

Ribeiro, F., Ferreira, P., Araujo, M., (2011).The inclusion of social aspects in power planning. Renewable Sustainable Energy Review 15, 4361 – 4369

Sandwell P, Alvin Chan N.L, Foster S, Nagpal D, Emmott C.J.M, Candelise C, Buckle S.J, Ekins-Daukes N, Gambhir A, Nelson J. (2016). Off-grid solar photovoltaic systems for rural electrification and emissions mitigation in India, Solar Energy Materials and Solar Cells, 156, 147 – 156.

Sheinbaum-Pardo, C., Ruiz-Mendoza, B.J., Rodriguez-Padilla, V., (2012). Mexican energy policy and sustainability indicators. Energy Policy 46, 278 –283

Tsiaras, E., Papadopoulos, D.N., Antonopoulos, C.N., Papadakis, V.G., Coutelieris, F.A., (2020). Planning and assessment of an off-grid power supply system for small settlements. Renewable Energy 149, 1271-1281

Wuestenhagen, R., Wolsink, M., Buerer, M.J., (2007). Social Acceptance of Renewable Energy Innovation: an Introduction to the Concept, Energy Policy 35, 2683 - 2691

Testing causalities within the Eurozone economic space at the interface of energy and tourism

George Ekonomou
Department of Planning and Regional Development, School of Engineering, University of Thessaly, Volos
goikonomou@uth.gr

Abstract
The purpose of the present study lies in investigating cointegrating and causality relationships between two important sectors in our modern world, namely energy and tourism. We define energy in terms of primary energy consumption. We use second generation unit root tests to examine if variables under consideration are stationary. We employ cointegrating and causality tests to search for potential longrun relationships and direction of causalities. We contribute in the relevant discussion in three ways. We use the concept of market segments in the relevant econometric models to define tourism in terms of leisure tourism spending. We also include internal consumption, by international and domestic visitors, instead of international receipts when searching for causalities. Additionally, we take into consideration total Gross Domestic Product (GDP) generated exclusively by tourism sector, an issue that is less visible in relevant studies. Research findings revealed that all proxies of tourism are mutually influenced with primary energy consumption. As a result, an increase (decrease) to each of them will cause an increase (decrease) on primary energy consumption in the same direction. Practical implications require collaborative management across tourism stakeholders to efficiently use energy within the context of sustainable development.

Keywords: Energy, environment, tourism.

JEL Codes: N7; F64; Z3.

Use of indexes in evaluating environmental and health efficiency

George Halkos & Georgia Argyropoulou
Laboratory of Operations Research,
Department of Economics, University of Thessaly
halkos@econ.uth.gr, geargyropoulou@uth.gr

Abstract
According the literature, there is a strong link between air pollutants to many types of health problems of many body systems. In this research two different Data Envelopment Analysis (DEA) models and two indexes are used in order to evaluate the efficiency of pollutant management at the expense of health. Firstly, two variations of the simple DEA model are used to estimate the efficiencies of 18 European countries for the years 2000, 2005, 2010, 2014, 2015 and 2016. The first variation uses labour and capital as inputs and GDP/c and mortality from exposure to PM2.5 as desirable and undesirable outputs respectively, while the second variation the environmental related tax revenues is used as additional input. The results derived are bias corrected to obtain the accurate efficiency scores of every country considered. Secondly, a two-stage DEA model is used to estimate the efficiencies of 23 countries for the time period 1990-2017, using capital, labor, and energy consumption as inputs, GDP as a desirable intermediate which is going out of the system, and sulfur oxides as an undesirable intermediate and respiratory disease deaths as an undesirable output. Finally, the simple mean Bertelsmann Index (BI) and the OECD's Distance Measure Index (DMI) are applied by using the air pollution, poisoning, poor sanitation, and unsafe water indicators of the third SDG goal for the evaluation of the efficiency of 107 United Nations countries for the period between 1990 and 2017. Useful conclusions can be drawn both in terms of the policies that can be implemented and in terms of the comparison of the above indicators.

Keywords: Environmental efficiency, Air pollution, Health effects, Good Health and Well-being, Environmental factors

JEL Codes: Q0;Q53.

1 Introduction

Air pollution refers to physical or chemical changes brought about by natural processes or human activities that result in air quality degradation. Air pollution is dis- criminated to indoor and outdoor. Indoor air pollution refers to the air we breathe at home, since we spend a large part of our lives indoors, while outdoor or ambient air pollution arises from both natural and man-made sources. Outdoor air pollution is associated with natural phenomena such as volcanoes, biological decay, lightning strikes and forest fires which emit sulphur and nitrogen oxides, as well as pollution from plants, grasses and trees, and particulate matter from dust storms. Man-made air pollution comes from our daily activities. The most common source of man- made outdoor air pollution is the burning of fossil fuels, such as coal, oil and gas, in power stations, refineries, industries, homes and road vehicles

Air pollution has had adverse health effects throughout history. The importance of ambient air pollution was first evaluated in the 20th century, mainly with the appearance of the air pollution disaster in London in 1952, which demonstrated that very high levels of particulate-based smog can cause dramatic increases in daily mortal- ity. The Great Smog of London, also called the Killer Fog of 1952 was a severe air- pollution even that affected the British capital of London in early December 1952.

A thick layer of smog (a word created from a combination of "smoke" and "fog") over the city was triggered by a mixture of weather fog and sulphurous smoke from coal fires (used to heat homes at the time). It lasted from Friday, 5 December to Tuesday, 9 December 1952 and then dispersed quickly when the weather changed. Those who were outside during the fog, suffered numerous health effects, mainly respiratory tract infections, such as hypoxia, bronchitis and bronchopneumonia, which finally caused the death of 4000–12,000 people.

The London smog of 1952 was not without precedent. Similar events occurred in the Meuse valley in 1930 (Firket, 1931) and in Donora, Pennsylvania, in 1948 (Ciocco and Thompson, 1961). The aforementioned historical severe episodes of air pollution provided indisputable evidence that high levels of air pollution have serious adverse effects on human health.

These health issues result in economic consequences such as high medical costs, lower productivity due to increase in missed working days, and the deterrence of foreign businesses and tourists. Additionally, air pollution causes acid rain that disperses toxic chemicals into air, water and soil, severely limiting available drinking water, killing forests and wildlife and harming overall crop productivity. Particularly, according to the OECD (2016) ambient air pollution is responsible for great economic losses. These losses include medical expenditures—an estimated US$21 billion globally in 2015—lost productivity resulting from pollution—related disease and premature death, and the cost of environmental degradation.

Appropriate allocation of resources in health care may guarantee that more people have admission to identical health care services when needed and rational allocation of health care resources should be a prime task rational for both social welfare economists and health policy makers (Kreng and Yang, 2011). Rationality and appropriate macroeconomic policies are really needed in such health problems with parameter estimates facing uncertainty. Amman and Kendrick (1999, 2000). discuss such issues in a general framework.

At the same time, there is an increasing interest in the analysis and comparison of efficiencies of health care systems relying on nonparametric and parametric applications. Varabyova and Müller (2016) review the current literature and present their findings on the efficiency of health systems in OECD countries. Halkos and Tzeremes (2011) consider the existing literature on performance measurement and apply conditional nonparametric models to measure public healthcare delivery efficiency from a regional perspective.

2 Background and Relevant Literature

Air pollutants can be grouped into four categories. First, gaseous pollutants like SO2, NOx, CO, ozone, Volatile Organic Compounds contribute to a great extent in composition variations of the atmosphere and are mainly due to combustion of fossil fuels. Sulphur dioxide (SO2) is highly reactive gas with a

pungent irritating smell. Carbon Monoxide (CO) is an odourless, colourless gas which forms when the carbon in fuels doesn't completely burn. Its main sources are combustion processes from vehicles, heating, coal-fired power generation, and biomass burning (Godish, 2003). Carbon monoxide can cause harmful health effects by reducing the amount of oxygen reaching the body's organs (like the heart and brain) and tissues. At extremely high levels, carbon monoxide can cause death (carbon monoxide poisoning). Ozone (O3) is composed of 3 oxygen atoms joined together. Ground level ozone is the main component of smog and is the product of the interaction between sunlight and emissions from sources such as motor vehicles and industry. Ozone can cause irritation and inflammation of eyes, nose, throat and lower airways: coughing, sore and scratchy throat or uncomfortable feeling in chest, reduced lung function: not able to breathe as deeply or vigorously as normally, exacerbation of asthma and chronic respiratory diseases such as chronic bronchitis, increased susceptibility to respiratory infection.

Volatile organic compounds (VOCs) are gases that are attributed by many indoor sources. Concentrations of most volatile organic compounds are higher in indoor air than outdoor air. VOCs can cause eye, nose and throat irritation, shortness of breath, headaches, fatigue, nausea dizziness and skin problems. Higher concentrations may cause irritation of the lungs, as well as damage to the liver, kidney, or central nervous system. Long-term exposure may also cause damage to the liver, kidneys or central nervous system. Some VOCs are also suspected of causing cancer and some have been shown to cause caner in humans. The health effects caused by VOCs depend on the concentration and length of exposure to the chemicals. Most people are not affected by short-term exposure to the low levels of VOCs found in homes. However, some people may be more sensitive, such as people with asthma.

Second, persistent organic pollutants such as dioxins, are pollutants which persist in the environment for long periods of time, and their effects are magnified as they move up through the food chain. Dioxins are found throughout the world in the environment and they accumulate in the food chain, mainly in the fatty tissue of animals. Dioxins are highly toxic and can cause reproductive and developmental problems, damage the immune system, interfere with hormones and also can cause cancer (WHO, 2016).

Third, heavy metals such as lead, mercury, cadmium, arsenic and other toxic metals are released into the environment by sever processes including waste and coal burning, metal mining and smelting, other industrial processes and volcanic emissions (Lee et al., 2002; Godish, 2003). At high concentrations they can become toxic and they can cause developmental retardation, several types of cancer, kidney damage, endocrine disruption, immunological, neurological and other disorders (Moreira and Moreira, 2004).

Finally, particulate matter (PM10 and PM2.5) is a complex mixture of particles of various sizes and chemical composition. The sources of particulates are many and include dust from soil and roads, diesel exhaust, emissions from combustion and industrial processes, construction and demolition, powdered pesticides, bioaerosols and volcanic ash (Dickey, 2000; Brook et al., 2004). Toxicity of particulates depends greatly on their size, with particulates less than 10 μm (PM10) or 2.5 μm (PM2.5) being considered especially dangerous since they can easily penetrate the lungs into the alveoli (Brunekreef, 2005).

Particle exposure can cause premature death in people with heart or lung disease, nonfatal heart attacks, irregular heart beat, aggravated asthma, decreased lung function, and increased respiratory symptoms such as irritation of the airways, coughing, or difficulty breathing (Atkinson et al., 2010; Cadelis et al., 2014; Correia et al., 2013; Fang et al., 2013; Meister et al., 2012). On another aspect, Ward et al. (2013) used data on PM2.5 concentration levels recorded in 338 hospitality venues across France, Greece, Ireland, Italy, Portugal, Turkey, and Scotland before and after the functioning of smoke-free legislation.

Table 1 shows the linking of the above mentioned air pollutants with the body systems which affect.

Table 1 Effects of pollutants on body systems

	SO_2	NO	Heavy metals	PM	O_3	CO	Dioxins
Respiratory system	x	x	x	x	x		
Cardiovascular system			x	x		x	x
Nervous system			x				x
Urinary system			x				
Digestive system							x
Exposure during pregnancy			x				x

From the above analysis, the link between air pollutants to many types of health problems of many body systems is obvious. As mentioned, air pollution is associated with large increases in medical expenses, morbidity and is estimated to cause about 800.000 annual premature deaths worldwide and a global burden of disease due to outdoor air pollution (Cohen et al., 2005).

Specifically, symptoms such as nose and throat irritation, followed by bronchoconstriction and dyspnea, especially in asthmatic individuals, are usually experienced after exposure to increased levels of Sulphur dioxide (Balmes et al., 1987) and nitrogen oxides (Kagawa, 1985). In addition, particulate matter that penetrates the alveolar epithelium (Ghio and Huang, 2004) and ozone initiate lung inflammation (Uysal and Schapira, 2003). Air pollutants such as nitrogen oxides increase the susceptibility to respiratory infections (Chauhan et al., 1998). Chronic exposure to ozone and certain heavy metals reduces lung function (Rastogi et al., 1991; Tager et al., 2005), while the later are also responsible for asthma, emphysema, and even lung cancer (Kuo et al., 2006; Nawrot et al., 2006).

Additionally, as for the respiratory system effects, there are many studies which have involved children and most of these studies have linked higher rates of asthma and other respiratory problems to higher outdoor air levels of priority pollutants such as particulates, ozone, sulfur and nitrogen oxides and carbon monoxide (Curtis et al., 2006). Therefore, there is a significant relationship between higher outdoor PM2.5 levels and more wheezing bronchitis in infants (Pino et al., 2004), while there is association of increasing levels of outdoor PM10, O3 and SO2 with significantly higher rates of childhood asthma and rhinitis (Penard-Morand et al., 2005).

Finally, low to moderate levels of outdoor air pollutants can greatly increase respiratory problems in the elderly (Curtis et al., 2006). According to a 1980–1995 study of Tokyo residents aged over 65 years has been found that increasing airborne outdoor PM10 concentrations were associated with significantly higher rates of asthma and bronchitis (Ye et al., 2001).

As for the cardiovascular system effects, outdoor air pollutants such as PM10 or PM2.5, O3, and NO2 have been associated with significantly higher rates of cardiac mortality and morbidity (Curtis et al., 2006). Carbon monoxide binds to hemoglobin modifying its conformation and reduces its capacity to transfer oxygen (Badman and Jaffe, 1996), while symptoms such as tachycardia, increased blood pressure and anemia due to an inhibitory effect on haematopoiesis have been observed as a consequence of heavy metal pollution (specifically mercury, nickel and arsenic) (Huang and Ghio, 2006). At last, epidemiologic studies have linked dioxin exposure to increased mortality caused by ischemic heart disease, while in mice, it was shown that heavy metals can also increase triglyceride levels (Dalton et al., 2001).

Air pollution can cause even cancer. Specifically, four out of five studies in Europe and the US have found that exposure to higher outdoor levels of PM10/PM2.5, vehicle traffic and NO2 are associated with significantly higher risk of lung cancer, while the fifth study showed a non-significant increased risk of lung cancer (Vineis et al., 2004). A British nationwide study from 1966 to 1980 found significantly higher cancer death rates for children living within one kilometer of areas of high industrial

emissions of PM10, NO2, total volatile organic compounds, benzene, dioxins, 1,3-butadiene, and benzo(a) pyrene (Knox, 2005).

Some outdoor air pollutants have also been linked to reproductive and develop- mental problems (Curtis et al., 2006). A study of births in Vancouver from 1985 to 1998 found that increasing levels of outdoor carbon monoxide and sulfur oxides significantly increased risk of preterm births (Liu et al., 2003). Other studies in Mexico and the Czech Republic have reported a relationship between ambient particulate levels and excess infant deaths (Loomis et al., 1999; Bobak and Leon, 1999). A Pennsylvania study found that higher outdoor air levels of PM10 and SO2 were associated with significantly higher rates of preterm birth (Sagiv et al., 2005). Finally, a Texas study found that higher levels of CO were associated with significantly higher levels of Teratology of Fallot, higher PM10 levels were associated with significantly higher levels of atrial septal defects and higher SO2 levels were associated with significantly higher rates of ventral septal defects (Gilboa et al., 2005).

Moreover, nervous is another system that can be affected by air pollutants. The nervous system is mainly affected by heavy metals (lead, mercury and arsenic and dioxins. Neurotoxicity leading to neuropathies, with symptoms such as memory disturbances, sleep disorders, anger, fatigue, hand tremors, blurred vision, and slurred speech, have been observed after arsenic, lead and mercury exposure (Ewan and Pamphlett, 1996; Ratnaike, 2003). Mercury is also responsible for certain cases of neurological cancer, while dioxins decrease nerve conduction velocity and impaired mental development of children (Thomke et al., 1999; Walkowiak et al., 2001).

Heavy metals can also induce kidney damage, as well they increase the risk of stone formation or nephrocalcinosis (Damek-Poprawa and Sawicka-Kapusta, 2003; Jarup, 2003; Loghman-Adham, 1997) and renal cancer (Boffetta et al., 1993; Vamvakas et al., 1993). It is rather important to mention that air pollutants can also have adverse digestive system effects. Particularly, dioxins induce liver cell damage (Kimbrough et al., 1977), as well as gastrointestinal and liver cancer (Mandal, 2005). Last but not least, it should be noted that numerous studies have linked exposures to higher levels of outdoor pollutants to significantly higher rates of mortality (Brunekreef and Holgate, 2002). The aforementioned episodes of extremely high air pollution in London in 1952 (Ministry of Public Health, 1954), the Meuse valley in 1930 (Firket, 1931), and in Donora, Pennsylvania, in 1948 (Ciocco and Thompson, 1961) demonstrated that particulate-based smog could produce large increases in the daily mortality rate.

Water pollution is also a source of health problems, since is strongly related to poor sanitation and the lack of safe drinking water and this is a problem faced by a third of the world's population (WHO, 2008). This poor sanitation and lack of safe water causes 1,6 million deaths per year (WHO, 2009).

According to WHO (2002), waterborne diseases are at the top of the list of infectious diseases. The most serious of them are cholera, acute diarrhea, legionellosis, and typhoid fever. Indeed, of particular concern is the fact that cholera has reappeared in Africa after about 100 years of absence (Ashbolt, 2004).

Finally, water deficiency and poor sanitary conditions are also associated with Hepatitis A and E viruses, rotaviruses, and the parasitic protozoa Giardia lambia (Ashbolt, 2004).

It is worth noting that air pollution health effects have also multiple economic consequences. According to OECD (2016) three different market impacts of air pollution are: reduced labor productivity, increased health expenditures and crop yield losses. Moreover, the additional cases of illness also lead to an impact on normal work activities. In 2060, lost working days at the global level are projected to be around 3.75 billion days (OECD, 2016). In addition, OECD (2014) using a Willingness-to-Pay approach found that the cost of the health impact of air pollution in OECD countries (including deaths and illnesses) was $1.7 trillion in 2010. At last, according to World Health Organization (2015) at 2010 the annual cost of premature deaths from air pollution across the countries of the European Region stood at $1.4 trillion and the overall annual cost of health impacts from air pollution at $1.6 trillion.

3 Methodologies and Data used

Two different Data Envelopment Analysis (DEA) models and two indexes are used in order to evaluate the efficiency of pollutant management at the expense of health:

i) the simple DEA model
ii) the two-stage DEA model
ii) Two SDG indexes:

- the simple mean Bertelsmann Index (BI)
- the OECD's Distance Measure Index (DMI)

3.1 The simple DEA model

3.1.1 The method

DEA is a non-parametric technique, which uses linear programming method for assessing the relative efficiency of a set of comparable decision-making units (DMUs), which consume several inputs to produce several outputs (Charnes et al., 1978). DEA compares each DMU's relative efficiency with the most efficient DMUs of the sample which is considered as the benchmark. DEA does not need any assumptions about the mathematical form of the production function. It is useful in uncovering relationships which remain hidden for other methodologies.

DEA assumes either constant returns to scale (CRS DEA models) or variable returns to scale (VRS DEA models). CRS reflects the fact that a change in inputs or outputs has a proportional change in the outputs or inputs respectively. VRS reflects the fact that an increase or decrease in inputs or outputs does not result in a proportional change in the outputs or inputs respectively (Cooper et al., 2011).

Under the assumption of free disposability, which means the possibility of not using or destroying inputs or outputs without costs and convexity, which implies that if two observation are possible, then all the linear combinations that lie between them are also possible, the DEA estimator of the production set for the measurement of efficiency for a given combination of inputs-outputs (x, y) can be defined as follows:

$$\widehat{\Psi}_{DEA} = \{(x,y) \in \mathbb{R}_+^{p+q} | y \leq \sum_{i=1}^{n} \gamma_i Y_i; x \geq \sum_{i=1}^{n} \gamma_i X_i, for\ (\gamma_i, \dots, \gamma_n)$$
$$s.t. \sum \gamma_i = 1; \gamma_i \geq 0, i = 1, \dots, n\}$$

where $\widehat{\Psi}_{DEA}$ under the constraint $\sum_{i=1}^{n} \gamma_i = 1$ allows for VRS and is often referred as $\widehat{\Psi}_{DEA-V}$ (Bander et al., 1984), while if the equality constrained $\sum_{i=1}^{n} \gamma_i = 1$ is dropped, then $\widehat{\Psi}_{DEA}$ allows for CRS (Daraio and Simar, 2007).

Particularly, using and output-orientation, the estimator of the output efficiency score can be defined by solving the following linear program:

$$\hat{\lambda}(x_0, y_0) = \sup\{\lambda | (x_0, \lambda y_0) \in \widehat{\Psi}_{DEA}\},$$
$$\hat{\lambda}(x_0, y_0) = \{\max \lambda \, | \lambda y_0 \leq \sum_{i=1}^{n} \gamma_i Y_i; x_0 \geq \sum_{i=1}^{n} \gamma_i X_i; \lambda > 0, for\ (\gamma_i, \dots, \gamma_n)$$
$$s.t. \sum_{i=1}^{n} \gamma_i = 1; \gamma_i \geq 0; i = 1, \dots, n\}$$

While, using an input-orientation, the estimator of the input efficiency score can be defined by solving the following linear program (Daraio and Simar, 2007):

$$\hat{\theta}(x_0, y_0) = \inf\{\theta | (\theta x_0, y_0) \in \hat{\Psi}_{DEA}\},$$
$$\hat{\theta}(x_0, y_0) = \{\min \theta \mid \sum_{i=1}^{n} \gamma_i Y_i ; \theta x_0 \geq \sum_{i=1}^{n} \gamma_i X_i ; \theta > 0, for(\gamma_i, \dots, \gamma_n)$$
$$s.t. \sum_{i=1}^{n} \gamma_i = 1; \gamma_i \geq 0; i = 1, \dots, n\}$$

However, efficiency scores taken by the implementation of the traditional DEA models may be biased (Löthegren and Tambout, 1999). Simar and Wilson (1998) introduced the bootstrapping DEA method in order to correct this bias in the efficiency scores. Bootstrapping is a statistical procedure popularized by Efron (1979) resampling the original dataset with replacement iteratively in order to create simulated dataset.

The bootstrapping estimated bias of $\hat{\theta}(x, y)$ is obtained by the following:

$$\widehat{bias}[\hat{\theta}(x, y)] = B^{-1} \sum_{b=1}^{B} \hat{\theta}_b^*(x, y) - \hat{\theta}(x, y)$$

Hence, the bias corrected estimator is defined by the subtraction:

$$\tilde{\theta}(x, y) = \hat{\theta}(x, y) - \widehat{bias}[\hat{\theta}(x, y)]$$
$$= \hat{\theta}(x, y) - \left[B^{-1} \sum_{b=1}^{B} \hat{\theta}_b^*(x, y) - \hat{\theta}(x, y) \right]$$
$$= \hat{\theta}(x, y) - B^{-1} \sum_{b=1}^{B} \hat{\theta}_b^*(x, y) + \hat{\theta}(x, y)$$
$$= 2\hat{\theta}(x, y) - B^{-1} \sum_{b=1}^{B} \hat{\theta}_b^*(x, y)$$

where $\tilde{\theta}(x, y)$ is the bias corrected estimator,

$\hat{\theta}(x, y)$ is the estimator of $\theta(x, y)$,
$\hat{\theta}^*(x, y)$ is the estimator of $\hat{\theta}(x, y)$,

B is the number of the bootstrapping generated pseudo – samples $X_n^{*,b}$, and $\hat{\theta}_b^*(x, y)$ is the Monte Carlo approximation of the $\hat{\theta}^*(x, y)$ distribution ($b = 1, \dots, B$).

Then, using the bootstrap (Simar and Wilson 1998) algorithm a Return To Scale (RTS) test is then carried out with the null hypothesis given as:

$$H_0: \Psi^\theta \text{ is globally CRS}$$

and the alternative hypothesis given as:

$$H_1: \Psi^\theta \text{ is VRS}$$

It is used as test statistics the mean of the ratios of the efficiency scores:

$$T(X_n) = \frac{1}{n}\sum_{i=1}^{n}\frac{\hat{\theta}_{CRS,n}(x_i, y_i)}{\hat{\theta}_{VRS,n}(x_i, y_i)}$$

By construction $\hat{\theta}_{CRS,n}(x_i, y_i) \leq \hat{\theta}_{VRS,n}(x_i, y_i)$ and we reject the null hypothesis if the statistics T is too small. The p-value of the null-hypothesis is obtained by computing:

$$p - value = Prob[T(X_n) \leq T_{obs} | H_0 is\ true]$$

where T_{obs} is the value of T computed on the original observed sample X_n.
Due to the difficulty of p-value's accurate calculation, this value is approximated by using the bootstrap (Simar and Wilson, 1998) algorithm as follows:

$$p - value \approx \sum_{b=1}^{B}\frac{I(T^{*,b} \leq T_{obs})}{B}$$

where $T^{*,b} = T(X_n^{*,b})$.

3.1.2 The empirical Application

In our analysis there are two DEA model specifications. The first one uses Capital Stock and Labor Force as two inputs in a production function setup, while Gross Domestic Production (GDP) is taken as desirable output and Mortality as undesirable (bad) output (Model 1). The second model specification uses Environmentally Related Tax Revenue, Capital Stock and Labor Force as three inputs together with Gross Domestic Production (GDP) as desirable output and Mortality as undesirable (bad) output (Model 2).
Having to cope with the undesirable output of mortality due to pollution, a directional distance function is employed.
The used data concern the years 2000, 2005, 2010, 2014, 2015 and 2016 and refer to the following European countries: Austria, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, the Netherlands, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, the United Kingdom.[1]
Tables 2 and 3 present respectively the basic descriptive statistics for the outputs and inputs used in our empirical application:

[1] The sources of the data used were the following:

- OECD (https://stats.oecd.org/index.aspx?queryid=72722)
- Annual macro-economic database of the European Commission (https://ec.europa.eu/info/business-economy-euro/indicators-statistics/economic-databases/macro-economic-databese-ameco/download-annual-data-set-macro-economic-database-ameco_en#capital-stock)
- Knoema World Data Atlas (https://knoema.com/pjeqzh/gdp-per-capita-by-country-statistics-from-imf-1980-2023?country=Portugal)

DataMarket (https://datamarket.com/data/set/1uty/labor-force#!ds=1uty!1w3z=2z.31.6r.56.q:1w40=2&display=line).

Table 2 Descriptive statistics of outputs (GDP/c and mortality)

Variable	N	Mean	SE mean	SD	Minimum	Q1	Median	Q3	Maximum
GDP/c 2000	18	17,924	2271	9637	3833	8872	21,660	26,169	30,799
Mortality 2000	18	456.0	23.4	99.1	288.6	379.4	468.7	523.1	639.3
GDP 2005	18	29,560	3352	142,21	8020	16,472	33,598	41,894	50,476
Mortality 2005	18	428.7	27.7	117.4	252.8	337.7	422.6	483.0	658.4
GDP 2010	18	34,647	3510	14,890	12,602	21,094	37,390	47,398	58,177
Mortality 2010	18	406.3	30.1	127.6	227.2	305.3	383.5	492.5	654.0
GDP 2014	18	37,346	3938	16,707	14,191	21,287	40,037	52,080	62,730
Mortality 2014	18	367.8	28.0	118.7	197.1	272.3	344.1	462.0	576.2
GDP 2015	18	32,991	3674	15,586	12,462	17,805	34,051	44,673	61,696
Mortality 2015	18	376.7	32.1	136.0	180.6	265.5	353.1	484.4	632.2
GDP 2016	18	33,346	3698	15,688	12,410	17,843	34,431	45,057	63,282
Mortality 2016	18	376.7	32.1	136.0	180.6	265.5	353.1	484.4	632.2

Table 3 Descriptive Statistics of inputs (tax revenues; net capital; labor)

Variable	N	Mean	SE mean	SD	Mini-mum	Q1	Median	Q3	Maximum
TaxRev 2000	18	33,856	20,947	88,870	104	3125	6198	33,356	384,806
NetCap 2000	18	1654	494	2094	21	257	599	2963	7039
Labor 2000	18	11,013,934	2,815,137	11,943,617	679,287	2,585,805	4,694,439	19,532,543	40,252,663
TaxRev 2005	18	50,007	34,618	146,870	259	4146	7912	36,493	634,646
NetCap 2005	18	1831	533	2260	31	336	665	3545	7382
Labor 2005	18	11,559,797	2,936,959	12,460,461	673,834	2,653,464	4,878,865	22,043,759	41,261,012
TaxRev 2010	18	59,583	43,006	182,461	433	4293	8628	42,505	787,238
NetCap 2010	18	2008	570	2417	43	408	767	4120	7687
Labor 2010	18	11,955,788	3,032,352	12,865,180	683,977	2,682,328	5,044,656	23,796,054	42,016,700
TaxRev 2014	18	60,731	42,313	179,517	553	4443	9009	48,112	775,369
NetCap 2014	18	2081	589	2500	51	435	815	4200	7928
Labor 2014	18	12,121,830	3,087,465	13,099,004	676,070	2,714,568	5,033,687	23,712,415	42,457,453
TaxRev 2015	18	67,046	48,390	205,300	523	4328	9216	49,340	885,617
NetCap 2015	18	2102	594	2521	52	441	829	4216	7992
Labor 2015	18	12,159,064	3,100,021	13,152,277	686,173	2,727,697	5,045,485	23,628,206	42,780,921
TaxRev 2016	18	71,380	52,210	221,510	614	4650	9555	49,789	954,996
NetCap 2016	18	2125	600	2545	54	455	839	4236	8066
Labor 2016	18	12,241,478	3,124,808	13,257,439	694,110	2,743,608	5,056,915	23,658,450	43,294,640

Table 4 shows the extracted p-values for the RTS test (with B=999), for each year and each of our two proposed models:

Table 4 Returns to scale test results

	2000	2005	2010	2014	2015	2016
Model 1 (inputs: net capital stock, labor outputs: GDP, mortality (bad output))						
p value	0.0781	0.0731	0.033	0.036	0.0631	0.0991
Model 2 (inputs: environmentally related tax revenue, net capital stock, labor outputs: GDP, mortality (bad output))						
p value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

As it is observed, in the case of model 1 and according to p-values we accept the null hypothesis of CRS, while for model 2 the p-value = 0.0000 for all years, hence we reject the null hypothesis of CRS.
Table 5 and 6 show respectively the rankings of countries along with their bias corrected efficiency scores for the first model and for the second model:

Table 5 DEA results of model 1

	2000		2005		2010		2014		2015		2016	
	Countries	Bias corrected scores	Countries	Bias corrected scores	Countries	Bias corrected scores	Countries	Bias Corrected Scores	Countries	Bias corrected scores	Countries	Bias corrected scores
1	Sweden	**0.882444**	Sweden	**0.821242**	Sweden	**0.86907**	Sweden	**0.884537**	Sweden	**0.794267**	Sweden	**0.798027**
2	France	**0.84971**	Finland	**0.785117**	Finland	**0.795618**	Finland	**0.826415**	Finland	0.720853	Finland	0.710329
3	Finland	**0.837696**	France	**0.774231**	France	**0.774742**	France	**0.774352**	France	0.677596	France	0.674966
4	Estonia	**0.803552**	Netherlands	0.722003	Ireland	**0.757946**	Ireland	*0.747022*	UK	0.665903	Netherlands	0.652525
5	Denmark	**0.768044**	UK	0.718108	Netherlands	**0.750705**	Netherlands	*0.744198*	Netherlands	0.655794	Estonia	0.652366
6	UK	**0.757856**	Austria	0.682486	Denmark	*0.738699*	Slovenia	*0.742821*	Estonia	0.648282	UK	0.643805
7	Netherlands	0.748521	Germany	0.67555	Slovenia	0.716423	UK	0.726187	Austria	0.625476	Slovenia	0.628397
8	Austria	0.73229	Spain	0.675065	Estonia	0.708336	Denmark	0.716863	Slovenia	0.625198	Austria	0.624821
9	Germany	0.729558	Estonia	0.672556	UK	0.70239	Austria	0.701382	Germany	0.615697	Germany	0.611824
10	Italy	0.702206	Slovenia	0.669806	Austria	0.701144	Estonia	0.686891	Ireland	0.607745	Spain	0.609401
11	Spain	0.692854	Ireland	0.664018	Spain	0.696879	Germany	0.678738	Spain	0.606678	Ireland	0.595819
12	Ireland	0.681996	Italy	0.661728	Germany	0.675026	Spain	0.666726	Italy	0.58297	Italy	0.583688
13	Slovenia	0.676335	Denmark	0.650791	Italy	0.655364	Italy	0.629651	Denmark	0.573063	Denmark	0.565243
14	Portugal	0.623453	Portugal	0.596649	Portugal	0.598948	Slovak Rep	0.605159	Portugal	0.55643	Portugal	0.55545
15	Greece	0.602821	Greece	0.587437	Greece	0.589571	Portugal	0.588967	Slovak Repc	0.537272	Slovak Repc	0.543338
16	Poland	0.535802	Poland	0.530957	Slovak Rep	0.584329	Greece	0.560819	Greece	0.536875	Greece	0.534771
17	Hungary	0.526177	Hungary	0.507354	Poland	0.539917	Poland	0.540738	Poland	0.526314	Poland	0.525434
18	Slovak Rep	0.503248	Slovak Rep	0.49335	Hungary	0.513666	Hungary	0.512231	Hungary	0.50362	Hungary	0.501592

Table 6 DEA results of model 2

	2000		2005		2010		2014		2015		2016	
	Countries	Bias corrected scores	Countries	Bias corrected scores	Countries	Bias corrected scores	Countries	Bias corrected scores	Countries	Bias corrected scores	Countries	Bias corrected scores
1	UK	**0.868236**	Denmark	**0.833833**	Sweden	**0.883772**	Sweden	**0.851795**	Sweden	0.744609	Sweden	0.746254
2	Sweden	**0.857092**	Sweden	**0.815065**	Netherlands	**0.842943**	Denmark	**0.818554**	Slovenia	0.725485	Slovenia	0.709385
3	Denmark	**0.854859**	France	**0.789577**	Denmark	**0.817526**	Netherlands	**0.802549**	France	0.683359	France	0.688232
4	France	**0.836409**	UK	**0.779883**	Finland	**0.791318**	Slovenia	**0.792966**	Denmark	0.682057	Denmark	0.668391
5	Netherlands	**0.814632**	Netherlands	**0.767479**	France	**0.775767**	France	**0.753952**	UK	0.642245	Spain	0.649701
6	Slovenia	**0.784655**	Spain	0.720631	Austria	**0.767606**	Austria	**0.751077**	Spain	0.636594	UK	0.637454
7	Germany	**0.761766**	Slovenia	0.719657	Spain	0.74017	Finland	0.736883	Netherlands	0.631743	Portugal	0.635632
8	Austria	**0.761572**	Finland	0.716711	Slovenia	0.728847	Germany	0.735242	Portugal	0.62797	Netherlands	0.624902
9	Ireland	**0.761427**	Portugal	0.691321	Germany	0.726778	UK	0.73172	Germany	0.61502	Germany	0.60715
10	Spain	**0.758101**	Italy	0.667154	UK	0.708894	Spain	0.697089	Italy	0.592541	Italy	0.597478
11	Portugal	**0.752609**	Germany	0.659731	Ireland	0.689849	Portugal	0.678191	Austria	0.586382	Greece	0.576014
12	Finland	0.730501	Austria	0.657963	Portugal	0.658384	Ireland	0.671649	Greece	0.570189	Austria	0.575134
13	Estonia	0.716229	Ireland	0.648035	Italy	0.657071	Italy	0.621457	Poland	0.563278	Hungary	0.566417
14	Italy	0.694278	Slovak Rep	0.632755	Greece	0.60892	Hungary	0.595466	Hungary	0.560564	Poland	0.565983
15	Greece	0.664906	Greece	0.624814	Poland	0.59761	Greece	0.594967	Finland	0.507145	Finland	0.521996
16	Hungary	0.658934	Hungary	0.624677	Hungary	0.594593	Slovak Rep	0.588244	Slovak Rep	0.505234	Slovak Rep	0.515531
17	Slovak Rep	0.651684	Poland	0.6075	Slovak Rep	0.592885	Poland	0.586017	Ireland	0.491779	Ireland	0.471577
18	Poland	0.648007	Estonia	0.57969	Estonia	0.50619	Estonia	0.474932	Estonia	0.219369	Estonia	0.246786

According to the bias corrected scores the following conclusions can be drawn:

- The rankings of countries after the bias correction in efficiency scores show that Sweden, Finland and France in the first model specification and Slovenia, Denmark, the UK, the Netherlands with Sweden and France in the second specification are efficient over the years with Sweden having the maximum efficiency scores. It was shown that there is a small percentage difference between the mean efficiency scores of the two models with the inclusion of environmentally tax revenues having a negligible influence in the efficiency scores.
- The most efficient countries in the first specification are Sweden, Finland and France.

- The most efficient countries in the second specification are Slovenia, Denmark, UK, Netherlands, Sweden and France.
- Sweden has on average the maximum efficiency scores.
- The less efficient countries in the first specification are Slovak Republic, Hungary, Poland and Greece having on average the highest rates of mortality and very low levels of GDP/c.
- The less efficient countries in the second specification are Slovak Republic, Hungary, Poland, Greece and Estonia having on average the highest rates of mortality and very low levels of GDP/c.
- A justification could be that richer countries tend to have lower death rates from air pollution (Ritchie and Roser, 2017). That is, countries with higher GDP/c may be able to attain better overall health, well being and healthcare/medical standards.
- On the contrary, low GDP/c levels could imply lower overall health and healthcare quality and consequently it could increase the burden of pollution-related disease (Akhtar et al., 2002).
- Finally, according to the following Table 7 which presents a summary of the average efficiency ratings for all the countries, it could be derived that there is a small percentage difference between the mean efficiency scores of the two models. Thus, the addition of the environmentally related tax revenue has a little effect to the efficiency scores.

Table 7 Summary of the mean efficiency scores

	Mean efficiency scores		
	Model 1	Model 2	% Change
2000	0.703031	0.754217	7.28
2005	0.660469	0.696471	5.45
2010	0.706183	0.704951	−0.17
2014	0.6916	0.693486	0.27
2015	0.614446	0.588087	−4.29
2016	0.611766	0.589112	−3.70

3.2 The two-stage DEA model

Two-stage DEA are systems with more than one process which are linked with each other (Kao, 2009) through outputs of the first stage which are called intermediate variables and become the inputs of the second stage (Zha and Liang, 2010).

Two-stage DEA approach has been used in many studies to measure healthcare, environmental and energy efficiencies.

3.2.1 The method

There are two basic structures, series and parallel. In a series structure as shown in Fig.1, the whole internal processes are connected in a series form where outputs of each stage become inputs of the next stage as intermediate dataset. In this case, a DMU is efficient only if all its processes are efficient (Shahroudi et al., 2011).

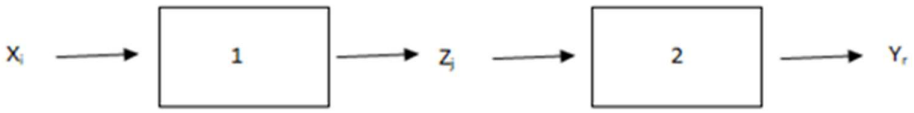


Figure 1: A simple two-stage DEA series structure

Instead, in a parallel structure, all processes operate independently as shown in Fig. 2 (Keikha-Javan and Rostamy-Malkhalifeh, 2016).

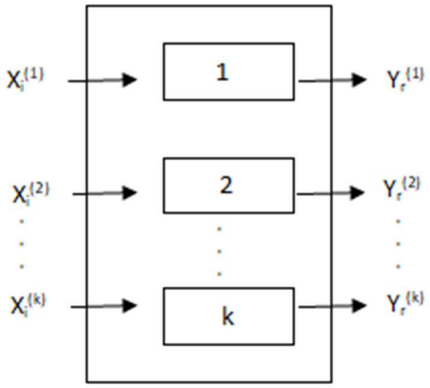


Figure 2: A parallel structure

According to Halkos et al. (2014) there are four classifications for a two-stage DEA system:

i) The independent two-stage DEA system, in which there is no possible interaction between the two stages (Wang et al., 1997; Seiford and Zhu, 1999).
ii) The connected two-stage DEA approach, in which the calculation of the overall efficiency takes into account the interactions between the two stages (Chen and Zhu, 2004).
iii) The relational two-stage DEA model, in which there is a mathematical relationship connecting the overall and individual stage efficiencies either additively (Chen et al., 2009) or multiplicatively (Kao and Hwang, 2008).
iv) Finally, the game theory models (Liang et al., 2006, 2008) which investigate the supply chain as a seller-buyer game under non-cooperative and cooperative assumptions.

In the existing bibliography, there are enough two-stage DEA studies which include undesirable variables by applying the additive Chen et al. (2009) model. For the first time, the undesirable variables are incorporated in a multiplicative Kao and Hwang (2008) model, using R programming language. (R is a free and open-source programming language and environment developed by Ross Ihaka and Robert Gentleman in 1993 which is used in statistical computing, data analytics and scientific research.)
The multiplicative two-stage model (Kao and Hwang, 2008) is based on the conventional CCR (Charnes et al, 1978) DEA model for measuring the efficiency of DMU_p, under the assumption of constant returns-to-scale. According to this model if we denote $X_{ij}, i = 1, \dots, m$ as the i-th input of j-th DMU (j=1,…,n) and $Y_{rj}, r = 1, \dots, s$ as the r-th output of j-th DMU (j=1,…,n), then the efficiency of DMU_p is computed as:

$$E_p = Max \frac{\sum_{r=1}^{S} w_r Y_{rp}}{\sum_{i=1}^{m} v_i X_{ip}} \quad (1)$$
$$\text{s.t. } \frac{\sum_{r=1}^{S} w_r Y_{rj}}{\sum_{i=1}^{m} v_i X_{ij}} \leq 1,\ j = 1, \dots, n$$
$$w_r, v_i \geq a, r = 1, \dots, s; i = 1, \dots, m$$

where α is a small non-Archimedean number (Charnes et al, 1979; Charnes and Cooper, 1984). According to the above model each DMU applies m inputs in order to produce s outputs, while E_p is the relative efficiency score of DMU_p, where E_p=1 indicates that DMU_p is efficient and E_p<1 indicates that DMU_p is inefficient.
Model (1) is a linear fractional program which can be transformed into the following linear program:

$$E_p = Max \sum_{r=1}^{S} w_r Y_{rp} \quad (2)$$
$$\text{s.t. } \sum_{i=1}^{m} v_i X_{ip} = 1$$
$$\sum_{r=1}^{S} w_r Y_{rj} - \sum_{i=1}^{m} v_i X_{ij} \leq 0, j = 1, \dots, n$$
$$w_r, v_i \geq a, r = 1, \dots, s; i = 1, \dots, m$$

Considering the series two-stage DEA process shown in Figure 1, the efficiencies of DMU_p in the first and the second stages are respectively defined as

$$E_p^1 = \frac{\sum_{d=1}^{D} h_d^1 Z_{dp}}{\sum_{i=1}^{m} v_i X_{ip}} \text{ and } E_p^2 = \frac{\sum_{r=1}^{S} w_r Y_{rp}}{\sum_{d=1}^{D} h_d^2 Z_{dp}}$$

where $v_i\ (i = 1, \dots, m)$ and $h_d^1\ (d = 1, \dots, D)$ are the input and output weights in the first stage and $h_d^2\ (d = 1, \dots, D)$ and $w_r\ (r = 1, \dots, s)$ are the input and output weights in the second stage.
The efficiency DEA models of stage 1, E_p^1, and stage 2, E_p^2, according to Kao and Hwang (2008) are documented as follows:

$$E_p^1 = Max \frac{\sum_{d=1}^{D} h_d Z_{dp}}{\sum_{i=1}^{m} v_i X_{ip}} \quad (2i)$$
$$\text{s.t. } \frac{\sum_{d=1}^{D} h_d Z_{dj}}{\sum_{i=1}^{m} v_i X_{ij}} \leq 1,\ j = 1, \dots, n$$
$$h_d, v_i \geq a, d = 1, \dots, D; i = 1, \dots, m$$
$$E_p^2 = Max \frac{\sum_{r=1}^{S} w_r Y_{rp}}{\sum_{d=1}^{D} h_d Z_{dp}} \quad (2ii)$$
$$\text{s.t. } \frac{\sum_{r=1}^{S} w_r Y_{rj}}{\sum_{d=1}^{D} h_d Z_{dj}} \leq 1,\ j = 1, \dots, n$$
$$w_r, h_d \geq a, r = 1, \dots, s; d = 1, \dots, D$$

These two models are essentially the same as model (1). The overall efficiency model which links the two sub-processes introduced by Kao and Hwang (2008) as follows:

$$E_p = Max \frac{\sum_{r=1}^{S} w_r Y_{rp}}{\sum_{i=1}^{m} v_i X_{ip}} \quad (3)$$
$$\text{s.t. } \frac{\sum_{r=1}^{S} w_r Y_{rj}}{\sum_{i=1}^{m} v_i X_{ij}} \leq 1,\ j = 1, \dots, n$$
$$\frac{\sum_{d=1}^{D} h_d Z_{dj}}{\sum_{i=1}^{m} v_i X_{ij}} \leq 1, j = 1, \dots, n$$

$$\frac{\sum_{r=1}^{S} w_r Y_{rj}}{\sum_{d=1}^{D} h_d Z_{dj}} \leq 1, j = 1, \dots, n$$
$$w_r, v_i, h_d \geq a, r = 1, \dots, s; i = 1, \dots, m; d = 1, \dots, D$$

By applying Charnes and Cooper (1962)'s transformation, models (2i), (2ii) and (3) can be converted into the linear programs (LP) for solution, as follows:

$$E_p^1 = Max \sum_{d=1}^{D} h_d Z_{dp} \quad (4i)$$
$$\text{s.t. } \sum_{i=1}^{m} v_i X_{ip} = 1$$
$$\sum_{d=1}^{D} h_d Z_{dj} - \sum_{i=1}^{m} v_i X_{ij} \leq 0, j = 1, \dots, n$$
$$h_d, v_i \geq a, d = 1, \dots, D; i = 1, \dots, m$$

$$E_p^2 = Max \sum_{r=1}^{S} w_r Y_{rp} \quad (4ii)$$
$$\text{s.t. } \sum_{d=1}^{D} h_d Z_{dp} = 1$$
$$\sum_{r=1}^{S} w_r Y_{rj} - \sum_{d=1}^{D} h_d Z_{dj} \leq 0, j = 1, \dots, n$$
$$w_r, h_d \geq a, r = 1, \dots, s; d = 1, \dots, D$$

$$E_p = Max \sum_{r=1}^{S} w_r Y_{rp} \quad (5)$$
$$\text{s.t. } \sum_{i=1}^{m} v_i X_{ip} = 1$$
$$\sum_{r=1}^{S} w_r Y_{rj} - \sum_{i=1}^{m} v_i X_{ij} \leq 0, j = 1, \dots, n$$
$$\sum_{d=1}^{D} h_d Z_{dj} - \sum_{i=1}^{m} v_i X_{ij} \leq 0, j = 1, \dots, n$$
$$\sum_{r=1}^{S} w_r Y_{rj} - \sum_{d=1}^{D} h_d Z_{dj} \leq 0, j = 1, \dots, n$$
$$w_r, v_i, h_d \geq a, r = 1, \dots, s; i = 1, \dots, m; d = 1, \dots, D$$

After solving model (5) we take the optimal multipliers w_r^*, v_i^* and h_d^*. Hence, the efficiencies are obtained as:

$$E_p = \frac{\sum_{r=1}^{S} w_r^* Y_{rp}}{\sum_{i=1}^{m} v_i^* X_{ip}}, \; E_p^1 = \frac{\sum_{d=1}^{D} h_d^* Z_{dp}}{\sum_{i=1}^{m} v_i^* X_{ip}}, \; E_p^2 = \frac{\sum_{r=1}^{S} w_r^* Y_{rp}}{\sum_{d=1}^{D} h_d^* Z_{dp}}$$

If we multiply the numerator and the denominator of E_p with the same quantity $\sum_{d=1}^{D} h_d^* Z_{dp}$, we have:

$$E_p = \frac{\sum_{r=1}^{S} w_r^* Y_{rp} \cdot \sum_{d=1}^{D} h_d^* Z_{dp}}{\sum_{i=1}^{m} v_i^* X_{ip} \cdot \sum_{d=1}^{D} h_d^* Z_{dp}} \Rightarrow E_p = \frac{\sum_{d=1}^{D} h_d^* Z_{dp}}{\sum_{i=1}^{m} v_i^* X_{ip}} \cdot \frac{\sum_{r=1}^{S} w_r^* Y_{rp}}{\sum_{d=1}^{D} h_d^* Z_{dp}} \Rightarrow E_p = E_p^1 \cdot E_p^2$$

However the optimal coefficients solved from model (5) may not be unique; thus, the product $E_p = E_p^1 \cdot E_p^2$ would not be unique. Consequently, the comparison of either E_p^1 or E_p^2 among all DMUs lack a common basis. A solution to this problem could be to find the set of multipliers which produces the largest E_p^1 while maintaining the overall efficiency score calculated from model (5) at E_p. Therefore, model (6) was introduced by Kao and Hwang (2008) as follows:

$$E_p^1 = Max \sum_{d=1}^{D} h_d Z_{dp} \quad (6)$$
$$\text{s.t. } \sum_{i=1}^{m} v_i X_{ip} = 1$$
$$\sum_{r=1}^{S} w_r Y_{rp} - E_p \sum_{i=1}^{m} v_i X_{ip} = 0$$

$$\sum_{r=1}^{S} w_r Y_{rj} - \sum_{i=1}^{m} v_i X_{ij} \leq 0, j = 1, \dots, n$$
$$\sum_{d=1}^{D} h_d Z_{dj} - \sum_{i=1}^{m} v_i X_{ij} \leq 0, j = 1, \dots, n$$
$$\sum_{r=1}^{S} w_r Y_{rj} - \sum_{d=1}^{D} h_d Z_{dj} \leq 0, j = 1, \dots, n$$
$$w_r, v_i, h_d \geq a, r = 1, \dots, s; i = 1, \dots, m; d = 1, \dots, D$$

After E_p^1 is calculated from model (6), the efficiency of the second stage is obtained by $E_p = E_p^1 \cdot E_p^2$ as $E_p^2 = \frac{E_p}{E_p^1}$.

3.2.2 The empirical Application

Our analysis is concerned with the performance measurement of 23 countries[2] for the time period 1990-2017. Table 8 presents the list of the 23 countries:

1	Australia	13	Japan
2	Austria	14	Luxembourg
3	Belgium	15	Netherlands
4	Canada	16	New Zealand
5	Denmark	17	Norway
6	Finland	18	Portugal
7	France	19	Spain
8	Germany	20	Sweden
9	Greece	21	Switzerland
10	Iceland	22	United Kingdom
11	Ireland	23	United States
12	Italy		

Table 8 The list of the 23 countries used in the analysis

Figure 3 shows the two-stage structure of our model:

[2] The sources of the data used were the following:
- European commission (https://ec.europa. eu/economy_finance/ameco/user/serie/ResultSerie.cfm)
- World Bank database (https://data.worldbank.org/)
- Eurostat (https://ec.europa.eu/eurostat/tgm/table.do?tab=table&plugin=1&language= en&pcode=sdg_07_11)
- The OECD (https://stats.oecd.org/)
- Our world in data (https://ourworldindata.org/grapher/respiratory-disease-deaths-by-age?country=GRC)

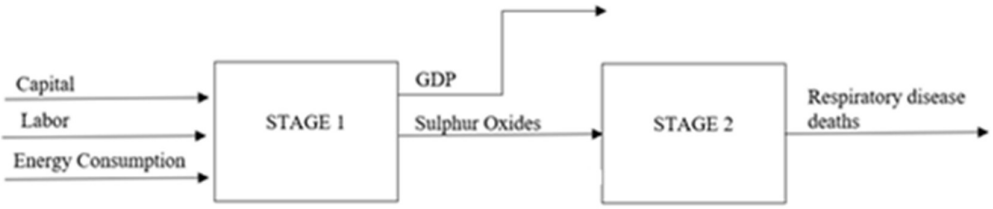


Figure 3: The presentation of the proposed two stage model

The production process using capital, labor, and energy as basic inputs produces its product (GDP) (as a good output), but at the same time, through the production process, negative effects on the environment are caused by the production of air pollutant (bad output) and thus on human health. Consequently, in our study, we use capital stock, labor force, and energy use as inputs of the first stage GDP as the desirable output which is coming out of the first stage and SO_x as undesirable output which turns into an input of the second stage production respiratory disease deaths as undesirable output of the second stage. It is worth mentioned that the most common cause of respiratory disease is smoking but as already clarified sulfur oxides is also one of the main factors which lead to respiratory disease.
Next is the modification of the multiplicative Kao and Hwang (2008) model. Let as denote as:
Let us denote as:

X_{ij}, the i-th input of j-th DMU (j=1,…,n)
Z_{dj}^{D}, the d-th desirable intermediate variable of j-th DMU (j=1,…,n)
Z_{kj}^{U}, the k-th undesirable intermediate variable of j-th DMU (j=1,…,n)
Y_{rj}^{U}, the r-th undesirable output of j-th DMU (j=1,…,n)

After the Seiford and Zhu (2002) transformation of the undesirable variables the Kao and Hwang (2008) model can be modified as:

$$E_p = Max \frac{\sum_{r=1}^{S} w_r Y_{rp}^{U}}{\sum_{i=1}^{m} v_i X_{ip}} \tag{7}$$

$$\text{s.t. } \frac{\sum_{r=1}^{S} w_r Y_{rj}^{U}}{\sum_{i=1}^{m} v_i X_{ij}} \leq 1, j = 1, \dots, n$$

$$\frac{\sum_{d=1}^{D} h_d Z_{dj}^{D} + \sum_{k=1}^{K} u_k Z_{kj}^{U}}{\sum_{i=1}^{m} v_i X_{ij}} \leq 1, j = 1, \dots, n$$

$$\frac{\sum_{r=1}^{S} w_r Y_{rj}^{U}}{\sum_{k=1}^{K} u_k Z_{kj}^{U}} \leq 1, j = 1, \dots, n$$

$$w_r, v_i, h_d, u_k \geq a, r = 1, \dots, s; i = 1, \dots, m; d = 1, \dots, D; k = 1, \dots, K$$

$$E_p^1 = Max \frac{\sum_{d=1}^{D} h_d Z_{dp}^{D} + \sum_{k=1}^{K} u_k Z_{kp}^{U}}{\sum_{i=1}^{m} v_i X_{ip}} \tag{8}$$

$$\text{s.t. } E_p = \frac{\sum_{r=1}^{S} w_r Y_{rp}^{U}}{\sum_{i=1}^{m} v_i X_{ip}}$$

$$\frac{\sum_{r=1}^{S} w_r Y_{rj}^{U}}{\sum_{i=1}^{m} v_i X_{ij}} \leq 1, j = 1, \dots, n$$

$$\frac{\sum_{d=1}^{D} h_d Z_{dj}^{D} + \sum_{k=1}^{K} u_k Z_{kj}^{U}}{\sum_{i=1}^{m} v_i X_{ij}} \leq 1, j = 1, \dots, n$$

$$\frac{\sum_{r=1}^{S} w_r Y_{rj}^U}{\sum_{k=1}^{K} u_k Z_{kj}^U} \leq 1, j = 1, \dots, n$$
$$w_r, v_i, h_d, u_k \geq a, r = 1, \dots, s; i = 1, \dots, m; d = 1, \dots, D; k = 1, \dots, K$$

By applying Charnes and Cooper's (1962) transformation, models (7) and (8) can be converted into the following linear programs (LP) for solution:

$$E_p = Max \sum_{r=1}^{S} w_r Y_{rp}^U \quad (9)$$
$$\text{s.t. } \sum_{i=1}^{m} v_i X_{ip} = 1$$
$$\sum_{r=1}^{S} w_r Y_{rj}^U - \sum_{i=1}^{m} v_i X_{ij} \leq 0, j = 1, \dots, n$$
$$\sum_{d=1}^{D} h_d Z_{dj}^D + \sum_{k=1}^{K} u_k Z_{kj}^U - \sum_{i=1}^{m} v_i X_{ij} \leq 0, j = 1, \dots, n$$
$$\sum_{r=1}^{S} w_r Y_{rj}^U - \sum_{k=1}^{K} u_k Z_{kj}^U \leq 0, j = 1, \dots, n$$
$$w_r, v_i, h_d, u_k \geq a, r = 1, \dots, s; i = 1, \dots, m; d = 1, \dots, D; k = 1, \dots, K$$
$$E_p^1 = Max \sum_{d=1}^{D} h_d Z_{dp}^D + \sum_{k=1}^{K} u_k Z_{kp}^U \quad (10)$$
$$\text{s.t. } \sum_{i=1}^{m} v_i X_{ip} = 1$$
$$\sum_{r=1}^{S} w_r Y_{rp}^U - E_p \cdot \sum_{i=1}^{m} v_i X_{ip} = 0$$
$$\sum_{r=1}^{S} w_r Y_{rj}^U - \sum_{i=1}^{m} v_i X_{ij} \leq 0, j = 1, \dots, n$$
$$\sum_{d=1}^{D} h_d Z_{dj}^D + \sum_{k=1}^{K} u_k Z_{kj}^U - \sum_{i=1}^{m} v_i X_{ij} \leq 0, j = 1, \dots, n$$
$$\sum_{r=1}^{S} w_r Y_{rj}^U - \sum_{k=1}^{K} u_k Z_{kj}^U \leq 0, j = 1, \dots, n$$
$$w_r, v_i, h_d, u_k \geq a, r = 1, \dots, s; i = 1, \dots, m; d = 1, \dots, D; k = 1, \dots, K$$

After E_p and E_p^1 from models (9) and (10) are calculated, the efficiency of the second stage is computed as $E_p^2 = \frac{E_p}{E_p^1}$.

Table 9 provides some basic descriptive statistics regarding the above variables used in our proposed two-stage DEA approach:

Table 9: Descriptive statistics of the variables used in two-stage DEA

	INPUTS			INTERMEDIATES		OUTPUTS
Years	**Energy use**	**Capital stock**	**Labor force**	**GDPc**	**SOx emissions**	**Respiratory disease deaths**
1990						
Mean	4545	2622.65	17306.53	35495.40	1892.15	14380.48
Standard deviation	2051.46	4491.70	29085.84	12786.98	4384.30	22191.64
1991						
Mean	4584	2683.14	17421.09	35719.02	1779.91	14681.13
Standard deviation	1996.13	4582.93	29267.44	13327.48	4205.96	22926.16
1992						
Mean	4530	2747.01	17529.70	35828.26	1715.79	14879.74
Standard deviation	1960.26	4683.58	29600.05	13487.82	4138.00	23460.02
1993						
Mean	4585	2804.13	17594.31	35953.55	1649.15	15387.09
Standard deviation	2030.23	4787.38	29784.91	13795.67	4073.12	24741.24
1994						
Mean	4632	2863.65	17715.19	36925.80	1573.02	15573.78
Standard deviation	2003.63	4899.61	30113.10	14173.76	3980.06	25416.92
1995						
Mean	4626	2926.79	17820.42	37760.63	1411.35	16062.78
Standard deviation	1869.28	5019.77	30339.27	14202.69	3473.06	26406.15
1996						
Mean	4773	2996.85	17965.96	38568.42	1359.55	16267.09
Standard deviation	1924.90	5157.42	30632.01	14373.23	3425.18	26914.48
1997						
Mean	4759	3069.38	18167.08	39848.00	1343.16	16428.39
Standard deviation	1869.06	5304.22	31079.58	14972.28	3510.18	27526.87
1998						
Mean	4805	3147.84	18317.49	41085.09	1317.86	32452.39
Standard deviation	1861.77	5467.42	31293.85	15428.95	3529.38	84806.38
1999						
Mean	4885	3232.43	18479.50	42479.71	1223.03	17267.35
Standard deviation	1990.59	5647.56	31559.44	16036.79	3260.32	29828.26
2000						
Mean	4965	3320.81	18709.37	44123.23	1170.11	17287.26
Standard deviation	2145.57	5839.03	32117.15	16885.64	3048.90	30509.31

2001						
Mean	4994	3402.63	18829.44	44758.37	1151.30	17385.17
Standard deviation	2053.63	6010.95	32304.34	17003.60	2982.49	31126.44
2002						
Mean	4992	3474.61	18988.09	45297.72	1109.77	17683.87
Standard deviation	2100.47	6159.44	32474.54	17276.99	2818.21	31768.26
2003						
Mean	5072	3548.58	19168.90	45718.83	1074.33	18015.09
Standard deviation	2145.33	6317.97	32775.99	17187.76	2777.54	32364.00
2004						
Mean	5130	3629.10	19307.70	46976.44	1041.19	17801.61
Standard deviation	2194.31	6496.00	32940.48	17633.16	2729.61	32258.58
2005						
Mean	5084	3717.63	19503.41	47940.52	1021.88	18200.22
Standard deviation	2172.86	6694.35	33302.22	18008.32	2728.86	33318.01
2006						
Mean	5168	3810.55	19727.66	49217.33	940.26	18298.22
Standard deviation	2439.31	6893.66	33694.40	18567.10	2464.88	33604.35
2007						
Mean	5194	3902.33	19926.07	50735.19	867.60	18620.00
Standard deviation	2735.74	7072.87	34015.63	19596.85	2205.43	34041.91
2008						
Mean	5248	3978.09	20086.23	50359.64	759.13	19085.70
Standard deviation	3005.49	7211.96	34231.90	19125.05	1958.07	35013.54
2009						
Mean	5047	4014.06	20123.75	48100.73	676.46	19345.70
Standard deviation	3076.93	7269.55	34207.91	18181.36	1741.17	35458.99
2010						
Mean	5202	4051.36	20138.90	48779.93	598.05	19587.87
Standard deviation	3125.86	7331.60	34151.42	18634.02	1489.43	35799.16
2011						
Mean	5038	4095.19	20150.68	49158.22	541.40	20115.00
Standard deviation	3335.76	7409.66	34078.89	18777.84	1275.08	36994.99
2012						
Mean	4956	4143.42	20274.56	48962.87	483.43	20401.22

Standard deviation	3224.23	7514.37	34304.77	18707.36	1045.77	37572.20
2013						
Mean	4957	4192.07	20346.65	49164.25	459.63	20725.13
Standard deviation	3330.71	7627.79	34396.05	18952.90	1005.55	38464.20
2014						
Mean	4804	4246.67	20423.23	49852.66	446.45	20864.48
Standard deviation	3302.85	7759.22	34494.57	19267.90	985.94	39052.12
2015						
Mean	4766	4304.35	20533.29	51043.12	392.48	21509.87
Standard deviation	3190.30	7898.46	34721.88	19746.77	821.00	40028.70
2016						
Mean	4730	4363.93	20717.29	51821.25	357.26	21751.87
Standard deviation	3227.03	8037.30	35132.55	20039.83	733.12	40673.13
2017						
Mean	4705	4429.80	20858.38	52741.57	339.38	22111.30
Standard deviation	3308.35	8188.50	35374.44	20067.07	687.55	41516.75

According to the above statistics, the following conclusions can be drawn:

- The growth of gross domestic product has been increasing over time.
- Despite the reduction of SO_X this increasingly course is accompanied by an increase in the number of people who lose their lives due to respiratory diseases.

The evaluated average efficiencies of our model are presented in Table 10 per year (analytical results per country can be found in Table A1 in the Appendix):

Table 10: The average efficiencies

	Average efficiencies		
Years	E_p	E_p^1	E_p^2
1990	0.547546	0.61644	0.846331
1991	0.542473	0.607091	0.85088
1992	0.557086	0.620947	0.855701
1993	0.560897	0.623009	0.85857
1994	0.574107	0.631741	0.866638
1995	0.571934	0.652835	0.838841
1996	0.56661	0.648942	0.835752
1997	0.586366	0.666486	0.842564
1998	0.606079	0.687881	0.844974
1999	0.606363	0.697219	0.836779
2000	0.575379	0.690258	0.804388
2001	0.559366	0.687896	0.78547
2002	0.538717	0.684773	0.76196
2003	0.529854	0.678833	0.756209
2004	0.545636	0.685324	0.771233
2005	0.552853	0.696239	0.768858
2006	0.511975	0.660613	0.751871
2007	0.463832	0.616989	0.732367
2008	0.408556	0.574631	0.696709
2009	0.343043	0.522199	0.649475
2010	0.300051	0.476948	0.627333
2011	0.228519	0.424444	0.548182
2012	0.150001	0.36071	0.44078
2013	0.147554	0.355766	0.441005
2014	0.130535	0.347675	0.404429
2015	0.075675	0.301508	0.290249
2016	0.014626	0.268443	0.098536
2017	0.019254	0.262715	0.117863

According to the efficiency scores of the two stages (E_p^1, E_p^2) and the overall efficiency scores (E_p), the following conclusions have been drawn:

- No country appears to be overall efficient. (E_p<1)
- The efficiency of all countries decreases over the years.
- In the last 3 years considered, the 23 selected countries performed relatively better in producing, but not well in reusing the undesirable pollutant output (SO_X). (E_p^1>E_p^2)

Consequently, despite the reduction of SO_X in the majority of the cases, the respiratory disease deaths are increasing over the time period 1990–2017 in most of the countries. This increase could be attributed to the other factors that lead to respiratory illnesses, such as $PM_{2.5}$, or smoking, in which there is also a decrease over time. On the other hand, taken together, all these factors that lead to problems in the respiratory system, can cause an increase in deaths because of respiratory diseases. In addition,

according to the World Health Organization, this increase could be a result of the age distribution of the population, as death rates of most diseases are strongly age-dependent, with risk rising proportionally with the raise of the age. (Documentation available at: https://www.who.int/data/gho/indicator-metadata-registry/imr-details/78, accessed November 23, 2021)

3.3 SDG indexes

The two most prominent methods are used for the third ("Good health and Well-being") Sustainable Development Goal's performance measurement at country level:

- The simple mean Bertelsmann Index – BI (Lafortune et al., 2018; Sachs et al., 2018)
- The OECD's Distance Measure Index – DMI (OECD, 2017)

3.3.1 The methods

i) Bertelsmann Index (Lafortune et al., 2018; Sachs et al., 2018)

According to Sachs et al (2018) indicators have to be normalized for comparability by rescaling the individual indicators from 0 to 100, using the following rescaling equation:

$$R = \frac{R_j - \min(R)}{\max(R) - \min(R)}$$

Where R_j the value of indicator j

After rescaling the variables, they have to be weighted and aggregated in order to compute the SDG index.

There are several methods of aggregating, for example the Leontief production function, geometric mean, and arithmetic mean. In this research we use the arithmetic mean method, which is widely used for its ease of application and explication, using the following formula:

$$T_i^I = \sum_{j=1}^{N} \frac{1}{N_i} \cdot \frac{R_{ij} - \min(R_{ij})}{\max(R_{ij}) - \min(R_{ij})}$$

where N_i is the number of SDG's indicators for country i,

R_{ij} is the value of indicator j in country i

ii) The Distance Measure Index (OECD, 2017)

This measure computes how far is a country from a specified target score which is referred to the specific indicator. For the computation of this index for a SDG target, we firstly find the maximum value between the division of the distance of a country from the target score of each indicator by the standard deviation of the indicator scores in all countries and zero. Then we divide this maximum valuer by the number of indicators and finally add them.

Thus, we have the following formula:

$$T_i^{II} = \sum_{j=1}^{N} \frac{1}{N_i} \max\left\{\frac{S_{ij} - K_j}{SD_j}, 0\right\}$$

where S_{ij} is the score value of indicator j for country i,

K_j is the target score for indicator j

N_i is the number of indicators
SD_j is the Standard Deviation of indicator j in all countries.
If a country has reached the target score, then $T_i^{II} = 0$

After the computation of the above indexes, the second index' scores for each country are forecast for each country in order to conclude which countries will have zeroed them by 2030.

3.3.2 The empirical Application

The research is focused on the SDG target 3.9:
"By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination"
Target 3.9 is linked with the following three indicators:

- **Indicator 3.9.1:** "Mortality rate attributed to household and ambient air pollution".
- **Indicator 3.9.2:** "Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene".
- **Indicator 3.9.3:** "Mortality rate attributed to unintentional poisoning."

Thus, the variables used in this analysis are:

a) Death Rate from air pollution
b) Death Rate from poisonings
c) Death Rate from poor sanitation
d) Death Rate from unsafe water

Our data concern the years between 1990 and 2017 for 107 countries (list in Table 11) which are selected according to the 2020 – 2021 World Bank income classification of countries, in order to have comparable results and to extract conclusions based on each country's income. According to this classification there are the following four income categories:

i) Low income	<1.036
ii) Lower – middle income	1.036 – 4.045
iii) Upper – middle income	4.046 – 12.535
iv) High income	>12.535

Thus, in our dataset there are 14 low income countries, 22 lower – middle income countries, 24 upper – middle income countries and 47 high income countries.[3]

[3] The source of the data used is: https://Ourworldindata.org

Low income countries	Lower-middle income countries	Upper-middle income countries	High income countries	
Afghanistan	Albania	Angola	Australia	Korea, Rep.
Burkina Faso	Algeria	Argentina	Austria	Kuwait
Burundi	Bangladesh	Armenia	Bahrain	Latvia
Eritrea	Bolivia	Azerbaijan	Barbados	Lithuania
Ethiopia	Cabo Verde	Belarus	Belgium	Luxembourg
Haiti	Cameroon	Bosnia and Herzegovina	Canada	Malta
Liberia	India	Brazil	Chile	Netherlands
madagascar	Kenya	Bulgaria	Croatia	New Zealand
Mali	Mauritania	China	Cyprus	Norway
Mozambique	Moldova	Georgia	Czech Republic	Oman
Sierra Leone	Mongolia	Guatemala	Denmark	Panama
Sudan	Morocco	Indonesia	Estonia	Poland
Tajikistan	Nepal	Iraq	Finland	Portugal
Uganda	Nicaragua	Jordan	France	Qatar
	Nigeria	Kazakhstan	Germany	Romania
	Pakistan	Malaysia	Greece	Saudi Arabia
	Philippines	Maldives	Hungary	Singapore
	Senegal	Montenegro	Iceland	Slovak Republic
	Tunisia	North Macedonia	Ireland	Slovenia
	Ukraine	Peru	Israel	Spain
	Uzbekistan	Russian Federation	Italy	Sweden
	Zimbabwe	Serbia	Japan	Switzerland
		Thailand		United Kingdom
		Turkey		United States
				Uruguay

Table 11 The list of the 107 countries by income category

i) Simple mean Bertelsmann index

According to the simple mean Bertelsmann Index (BI) formula the calculated scores are being normalized to the scale 0-1. The higher the BI score, the better the country's performance, and vice versa.

Table 12 bellow shows the average Bertelsmann index (BI) by income category for the years considered:

		Average Bertelsmann Index by income category													
	Income classification	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
1	Low income	0.503634	0.501782	0.502366	0.504524	0.509324	0.515555	0.519543	0.516243	0.51436	0.51832	0.518182	0.516768	0.524325	0.526152
2	Lower - middle income	0.708723	0.709687	0.711153	0.715111	0.719924	0.719652	0.728044	0.72869	0.729718	0.729702	0.726261	0.723142	0.727023	0.730095
3	Upper - middle income	0.84671	0.845472	0.843005	0.842932	0.846147	0.853172	0.859065	0.86172	0.863692	0.865333	0.861729	0.859142	0.86026	0.86256
4	High income	0.953048	0.953882	0.954087	0.954608	0.956034	0.958438	0.961096	0.961682	0.962233	0.963179	0.962469	0.961513	0.962024	0.962019

		Average Bertelsmann Index by income category													
	Income classification	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1	Low income	0.523041	0.519729	0.517144	0.514402	0.514064	0.506477	0.497774	0.4898	0.48243	0.475264	0.47158	0.472833	0.463617	0.458805
2	Lower - middle income	0.730025	0.728813	0.724102	0.720693	0.716392	0.709494	0.712225	0.710016	0.709658	0.708065	0.709123	0.711095	0.709534	0.707227
3	Upper - middle income	0.863904	0.864704	0.862343	0.862906	0.862801	0.858377	0.856499	0.853121	0.852365	0.851365	0.854384	0.857886	0.857503	0.855211
4	High income	0.962413	0.962033	0.959988	0.958332	0.958754	0.957713	0.957923	0.957392	0.956267	0.955519	0.957036	0.956761	0.956987	0.956101

Table 12: Average Bertelsmann Index by income category

The above table shows this positive relationship between the BI and income, since it is observed that as we move from the low-income countries to the high-income countries, the average value of the BI increases and this is observed in all the years considered.
In addition, there is a downward trend over time of the average BI in the two lowest income categories as in the 1st category (Low income) there is a fall of the average BI from 0,503634 in 1990 to 0,458805 in 2017 and in the 2nd category (Lower-middle income) there is a decrease from 0,708723 in 1990 to 0,707227 in 2017. On the contrary, it is observed an upward trend over time of the average BI in the two highest income categories, as in the 3rd category (Upper-middle income) there is a risen from 0,84671 in 1990 to 0,855211 in 2017 and in the 4th category (High income) there is an increase from 0,953048 in 1990 to 0,956101 in 2017.

A similar analysis follows for the Distance Measure Index:

ii) Distance Measure Index
This index shows how far each country is from its goal. Thus, the smaller the Distance Measure Index (DMI), the better the country's performance, and vice versa. As a target has been set the reduction of each variable by 40%.[4]
Table 13 below shows the average Distance Measure Index (DMI) by income category for the years considered:

[4] This percentage has been chosen since this is an achievable target (neither too strict, nor too lax).

		Average Distance Measure Index by income category													
	Income classification	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
1	Low income	1.338426	1.323295	1.305299	1.296445	1.27801	1.262573	1.252736	1.232451	1.214144	1.181515	1.145239	1.103926	1.063381	1.02697
2	Lower - middle income	0.843931	0.830276	0.816673	0.799062	0.783598	0.794925	0.765975	0.745083	0.7233	0.708883	0.690526	0.670697	0.654691	0.634574
3	Upper - middle income	0.517388	0.514713	0.518337	0.519189	0.509312	0.482167	0.455936	0.435536	0.419525	0.405898	0.397497	0.38792	0.383433	0.37505
4	High income	0.227128	0.21821	0.208363	0.202286	0.191622	0.179264	0.165007	0.159805	0.153586	0.143752	0.134622	0.131448	0.127855	0.126492

		Average Distance Measure Index by income category													
	Income classification	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1	Low income	0.992808	0.955777	0.922668	0.884254	0.844563	0.816144	0.810622	0.780799	0.747761	0.716273	0.685794	0.663618	0.641158	0.624434
2	Lower - middle income	0.615223	0.599443	0.594618	0.581021	0.581018	0.572132	0.541036	0.51454	0.483558	0.457209	0.43807	0.435279	0.416689	0.403194
3	Upper - middle income	0.360568	0.350065	0.337432	0.313065	0.301084	0.295252	0.288827	0.279332	0.259673	0.240288	0.219172	0.202463	0.18754	0.183975
4	High income	0.120575	0.118908	0.118019	0.117069	0.108966	0.100574	0.09101	0.085259	0.077464	0.071202	0.062468	0.062131	0.054774	0.053856

Table 13: Average Distance Measure Index by income category

The above table shows a negative relationship between countries' DMI performance and their income. As figure 4 shows, the DMI decreases over the time in the majority of the countries, which means that they are approaching the setting target of the variables reduction by 40%.

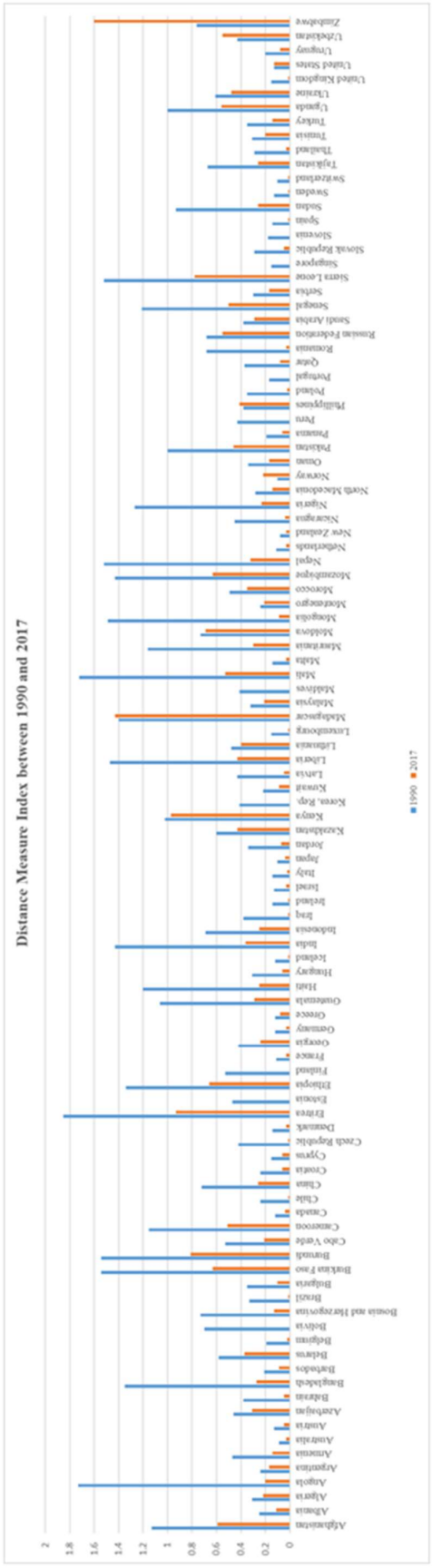


Figure 4: The Distance Measure Index between 1990 and 2017

After forecasting, it is extracted that the countries which will have reached their goal until 2030 are Angola, Bahrain, Belarus, Bolivia, Brazil, Bulgaria, Chile, Czech Republic, Estonia, Finland, France, Hungary, Iraq, Korea Rep., Latvia, Maldives, Nicaragua, Panama, Peru, Poland, Portugal, Qatar, Romania, Singapore, Slovenia, Sudan, Sweden and Switzerland. The majority of them belong to the upper – middle and high income categories. Exceptions are Bolivia and Maldives which belong to lower – middle income category and Sudan which belongs to the low income category.

Overall, can be concluded that high-income countries perform better on both indexes than low-income countries. Thus, it is more possible for the high-income countries to achieve the Sustainable Development health goals connected to environmental issues by 2030.

Comparatively, for the two indexes the following conclusions can be drawn:

- According to BI, the relationship between the index and income is clearer as the countries in first place are in the high income category, while those in last place belong to the low income category. Conversely, according to the DMI, Maldives is in first place despite belonging to the third income category, while Zimbabwe is in last place although it belongs to the second income category. Thus, BI seems more reliable compared to DMI.
- The BI seems to be a better indicator than DMI, since the first is based on the sizes of the variables, and therefore is more objective, while the second is based on the goal that is each time defined, which is subjective and depends on how strict or relaxed is the preferable.
- There is an antisymmetric relationship between them. This means that despite the emergence of BI as more reliable, on average one indicator confirms the other, and both of them confirm the relationship between the two indicators and per capita income. This is clear from the next figure:

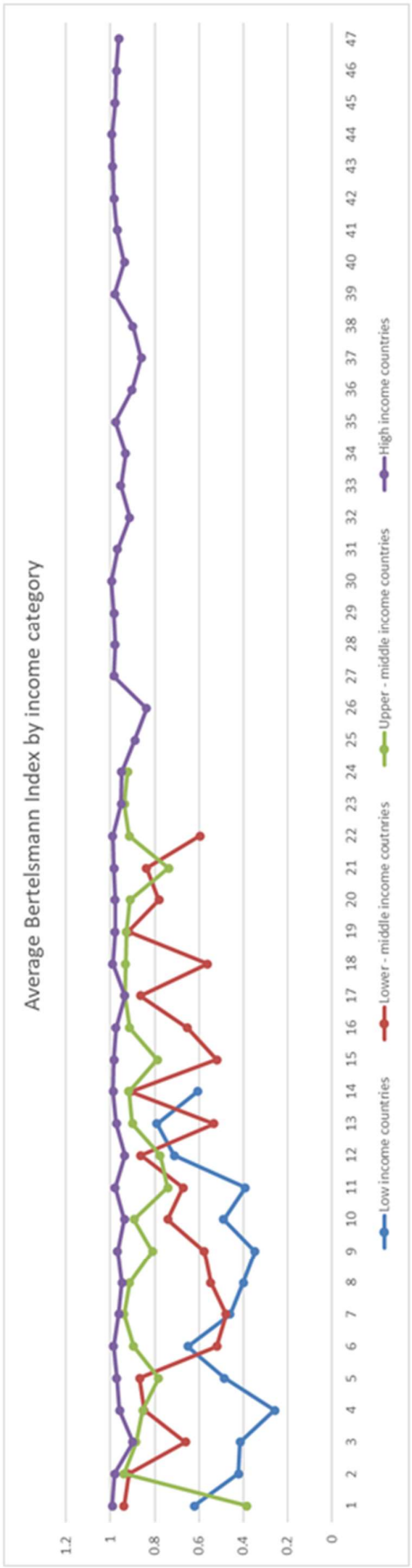


Figure 5: Average Bertelsmann Index by Income Category

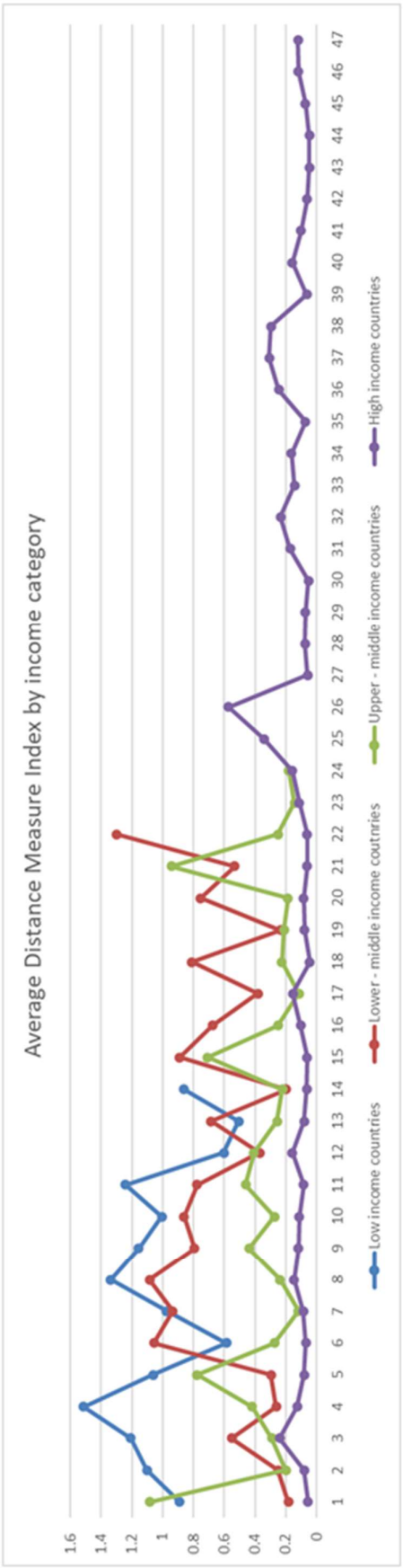


Figure 6: Average Distance Measure Index by Income Category

Consequently, wealthy countries achieve better environmental performance than poor countries. This lower index evaluation performance of low-income countries could be explained by poor policies or their reluctance to tackle the problems arising from air pollution.

4 Conclusions and Policy Implications

Human health is important both for individuals and for the society as a whole, as it increases happiness and well-being of people and contributes to economic growth. Economies with healthy people are more productive and concurrently save more resources. As it is already mentioned, air pollution causes severe health problems to humans. In this respect, governments having the necessary knowledge or information about the effects of pollution on public health have the ability to define such a policy in order to reduce as much as possible the health problems caused by pollution.

Specifically, environmental taxes and appropriately allocated subsidies may require governments to provide local authorities with the necessary legal. fiscal and institutional basis for coping with pollution locally. At the same time society awareness is important in informing residents of the severe effects of pollution and the long run character of the potential health problems.

As there is not a common way to tackle pollution, initiatives have to be planned for adequate energy policies. This necessitates thoughtful consideration of appropriate pollution control policies in energy with suitable regulations applied in urban centers where population is exposed to serious pollution.

In addition, there is a greater need for policies to support the low - income countries, for example, through the transfer of funds from the high - income countries to the low - income countries, to support investments with the ultimate aim of improving living conditions in these countries.

Additionally, one more important element is knowledge. According to the research of Giles-Corti et al (2019), in which the achievement of SDGs at the city level is studied, some guidance should be given to cities, regarding each of the targets' indicators, based on the required level of intervention, in order to achieve specific health and well-being outcomes. This policy, could be implemented in country level too. In this way, policies of enactment by states of targets lower than required to achieve the desired results could be prevented.

Finally, much important is the education. Thus, another policy could be the funding of training programs for the learning of hygiene rules in order to improve the hygienic conditions in the low-income countries.

References

Akhtar, R., Dutt, A. K., & Wadhwa, V. (2002). Health planning and the resurgence of malaria in urban India. In R. Akhtar (Ed.), *Urban health in third world* (pp. 65-92). New Delhi: APH Publishers.

Ashbolt NJ. 2004. Microbial contamination of drinking water and disease outcomes in developing regions. *Toxicology,* 198:229–38

Atkinson, R. W., Fuller, G. W., Anderson, H. R., Harrison, R. M. and Armstrong, B. (2010). Urban ambient particle metrics and health: a time-series analysis. *Epidemiology*, **21(4)**: 501-511.

Badman, D.G. and Jaffe, E.R. (1996). Blood and air pollution: state of knowledge and research needs. *Otolaryngology, Head and Neck Surgery*, **114(2)**: 205-208.

Balmes, J.R., Fine, J.M. and Sheppard, D. (1987). Symptomatic bronchoconstriction after short-term inhalation of sulfur dioxide. *The American Review of Respiratory Disease*, **136**: 1117-1121.

Banker, R., Charnes, A. and Cooper, W.W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science*, **30(9)**: 1078-1092.

Bobak M and Leon DA. (1999). The effect of air pollution on infant mortality appears specific for respiratory causes in the postneonatal period. *Epidemiology*, **10(6)**: 666-670.

Boffetta, P., Merler, E. and Vainio, H. (1993). Carcinogenicity of mercury and mercury compounds. *Scandinavian Journal of Work*, *Environment and Health*, **19(1)**: 1-7.

Brook RD, Franklin B, Cascio W, Hong Y, Howard G, Lipsett M, Luepker R, Mittleman M, Samet J, Smith SC Jr, Tager I (2004). Air pollution and cardiovascular disease: a statement for healthcare professionals from the expert panel on population and prevention science. *Circulation*, **109(21)**: 2655-2671.

Brunekreef, B. (2005). Epidemiological evidence of effects of coarse airborne particles on health. *European Respiratory Journal,* **26(2):** 309-318.

Brunekreef, B. and Holgate, S.T. (2002). Air pollution and health. *The Lancet*, **360(9341)**: 1233-1242

Cadelis, G., Tourres, R. and Molinie, J. (2014). Short-term effects of the particulate pollutants contained in Saharan dust on the visits of children to the emergency department due to asthmatic conditions in Guadeloupe (French Archipelago of the Caribbean). *PloS One*, **9(3):** e91136.

Charnes, A., & Cooper, W.W. (1984). The non-Archimedean CCR ratio for efficiency analysis: A rejoinder to Boyd and Färe. *European Journal of Operational Research, 15*, 333-334.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, **2(6)**: 429-444.

Charnes, A., & Cooper, W.W. (1962). Programming with linear fractional functionals, *Naval Research Logistics Quarterly, 9*, 181 – 186.

Charnes, A., Cooper, W.W., & Rhodes, E. (1979). Short communication: Measuring the efficiency of decision making units. *European Journal of Operational Research, 196*, 1170 – 1176.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*, 429–444.

Chauhan, A.J., Krishna, M.T., Frew, A.J. and Holgate, S.T. (1998). Exposure to nitrogen dioxide (NO2) and respiratory disease risk. *Reviews on Environmental Health*, **13(1-2)**: 73-90.

Chen, Y., Cook, W.D., Li, N., & Zhu, J. (2009). Additive efficiency decomposition in two-stage DEA, *European Journal of Operational Research, 196*, 1170–1176.

Chen, Y., & Zhu, J. (2004). Measuring information technology's indirect impact on firm performance. *Information Technology & Management Journal, 5(1–2)*, 9–22.

Ciocco A. and Thompson DJ. (1961). A follow-up on Donora ten years after: methodology and findings. *American Journal of Public Health and the Nation's Health*, **51(2)**: 155-164.

Cohen AJ, Ross Alexander H, Ostro B, Pandey KD, Kryzanowski M, Kunzail N, et al. (2005). The global burden of disease due to outdoor air pollution. *Journal of Toxicology and Environmental Health*, *Part A*, **68(13-14)**: 1301-1307.

Cooper, W.W., Seiford, L.M., Zhu, J. (2011). *Handbook on Data Envelopment Analysis*, International Series in Operations Research & Management Science, 2nd edition, Vol 164, Springer.

Correia, A. W., Pope III, C. A., Dockery, D. W., Wang, Y., Ezzati, M. and Dominici, F. (2013). The effect of air pollution control on life expectancy in the United States: an analysis of 545 US counties for the period 2000 to 2007. *Epidemiology*, **24(1)**: 23-31.

Curtis L., Rea W., Willis P. W., Fenyves E. and Pan Y. (2006). Adverse health effects of outdoor air pollutants. *Environment International*, **32(6)**: 815-830.

Dalton, T.P., Kerzee, J.K., Wang, B., Miller, M., Dieter, M.Z., Lorenz, J.N., Shertzer, H.G., Nerbert, D.W. and Puga, A. (2001). Dioxin exposure is an environmental risk factor for ischemic heart disease. *Cardiovascular Toxicology*, **1(4)**: 285-298.

Damek-Poprawa, M. and Sawicka-Kapusta, K., 2003. Damage to the liver, kidney, and testis with reference to burden of heavy metals in yellow-necked mice from areas around steelworks and zinc smelters in Poland. Toxicology, **186(1-2)**: 1-10.

Daraio, C. and Simar L. (2007). *Advanced Robust and Nonparametric Methods in Efficiency Analysis. Methodology and Applications*, *Springer, New-York*.

Dickey JH. (2000). Air pollution: overview of sources and health effects. *Disease-a-Month*, **46(9)**: 566-589.

Efron, B. (1979). Bootstrap methods: another look at the jackknife. *Annals of Statistics*, **7(1)**: 1-26.

Ewan, K.B. and Pamphlett, R. (1996). Increased inorganic mercury in spinal motor neurons following chelating agents. *Neurotoxicology*, **17**: 343-349.

Fang, Y., Naik, V., Horowitz, L. W. and Mauzerall, D. L. (2013). Air pollution and associated human mortality: the role of air pollutant emissions, climate change and methane concentration increases from the preindustrial period to present. *Atmospheric Chemistry and Physics*, **13(3)**: 1377-1394.

Firket, J. (1931). Sur les causes des accidents survenus dans la vallée de la Meuse, lors des brouillards de décembre 1930. *Bulletin et Memoires de l'Academie Royale de Medecine de Belgique*, **11**: 683-741.

Ghio, A.J. and Huang, Y.C. (2004). Exposure to concentrated ambient particles (CAPs): a review. *Inhalation Toxicology*, **16(1)**: 53-59.

Gilboa SM, Mendola P, Olshan AP, Langois PH, Savitz DA, Loomis D, et al. (2005). Relation between ambient air quality and selected birth defects. *Seven County Study, Texas, 1997–2000*, *American Journal of Epidemiology*, **162(3)**: 238-252.

Giles-Corti, B., Lowe, M., & Arundel, J. (2019). Achieving the SDGs: Evaluating indicators to be used to benchmark and monitor progress towards creating healthy and sustainable cities. *Health Policy,* 124(6), 581–590. https://doi.org/10.1016/j. healthpol.2019.03.001.

Godish T. (2003). *Air quality*. 4th edition. CRC Press Inc., Boca Raton, Florida: Lewis Books.

Halkos G. and Tzeremes N. (2011). A conditional nonparametric analysis for measuring the efficiency of regional public healthcare delivery: An application to Greek prefectures. Health Policy*, **103(1):** 73-82.*

Halkos, G. E., Tzeremes, N. G., & Kourtzidis, S. A. (2014). A unified classification of two-stage DEA models. *Surveys in Operations Research and Management Science, 19(1),* 1–16.

Huang, Y.C. and Ghio, A.J. (2006). Vascular effects of ambient pollutant particles and metals. *Current Vascular Pharmacology*, **4(3)**: 199-203.

Jarup, L. (2003). Hazards of heavy metal contamination. *British Medical Bulletin*, **68(1)**: 167-182.

Kagawa, J. (1985). Evaluation of biological significance of nitrogen oxides exposure. *The Tokai Journal of Experimental and Clinical Medicine*, **10(4)**: 348-353.

Kao, C. (2009). Efficiency decomposition in network data envelopment analysis: A relational model, *European Journal of Operational Research, 192*, 949–962.

Kao, C., & Hwang, S.-N. (2008). Efficiency decomposition in two-stage data envelopment analysis: An application to non-life insurance companies in Taiwan, *European Journal of Operational Research, 185*, 418–429.

Keikha- Javan, S., & Rostamy-Malkhalifeh, M. (2016). EFFICIENCY MEASUREMENT OF NDEA WITH INTERVAL DATA. *International Journal of Mathematical Modelling & Computations, 6(3 (SUMMER))*, 199-210.

Kimbrough, R.D., Carter, C.D., Liddle, J.A. and Cline, R.E. (1977). Epidemiology and pathology of a tetrachlorodibenzodioxin poisoning episode. *Archives of Environmental Health: An International Journal*, **32(2)**: 77-86.

Knox EG. (2005). Childhood cancers and atmospheric carcinogens. *Journal of Epidemiology & Community Health*, **59(2)**: 101-105.

Kreng V.B. and Yang C.T. (2011). The equality of resource allocation in health care under the National Health Insurance System in Taiwan. Health Policy, ***100(2-3)**: 203-210.*

Kuo, C.Y., Wong, R.H., Lin, J.Y., Lai, J.C. and Lee, H. (2006). Accumulation of chromium and nickel metals in lung tumors from lung cancer patients in Taiwan. *Journal of Toxicology and Environmental Health*, *Part A*, **69(14)**: 1337-1344.

Lee JT, Kim H, Song H, Hong YC, Cho YS, Shin SY, et al. (2002). Air pollution and asthma among children in Seoul, South Korea. *Epidemiology*, **13(4)**: 481-484

Liang, L. Cook, W., & Zhu, J. (2008). DEA models for two-stage processes: Game approach and efficiency decomposition, *Naval Research Logistics, 55*, 643–653.

Liang, L., Yang, F., Cook, W. D., & Zhu, J. (2006). DEA models for supply chain efficiency evaluation. *Annals of Operations Research, 145(1)*, 35–49.

Liu S, Knewski D, Shi Y, Chen Y and Burnett RT. (2003). Association between gaseous ambient air pollutants and adverse pregnancy outcomes in Vancouver, British Columbia. *Environmental Health Perspectives*, **111(14)**: 1773-1778.

Loghman-Adham, M. (1997). Renal effects of environmental and occupational lead exposure. *Environmental Health Perspectives*, **105(9)**: 928-939.

Loomis D, Castillejos M, Gold DR, McDonnel W and Borja-Abutro VH. (1999). Air pollution and infant mortality in Mexico City. *Epidemiology*, **10(2)**: 118-123.

Löthgren, M. and Tambour, M. (1999). Bootstrapping the data envelopment analysis Malmquist productivity index. *Applied Economics*, **31(4)**: 417-425.

Mandal, P.K. (2005). Dioxin: a review of its environmental effects and its aryl hydrocarbon receptor biology. *Journal of Comparative Physiology B*, **175(4)**: 221-230.

Meister, K., Johansson, C. and Forsberg, B. (2012). Estimated short-term effects of coarse particles on daily mortality in Stockholm, Sweden. *Environmental Health Perspectives*, **120(3)**: 431-436.

Ministry of Health (1954). *Mortality and Morbidity during the London Fog of December 1952.* Reports on Public Health and Medical Subjects No 95. London: London Ministry of Health, Great Britain.

Moreira, FR. and Moreira, JC. (2004). Effects of lead exposure on the human body and health implications. *Revista Panamericana de Salud Publica,* **15:** 119-129.

Nawrot, T., Plusquin, M., Hogervorst, J., Roels, H.A., Celis, H., Thijs, L., Vangronsveld, J., Van Hecke, E. and Staessen, J.A. (2006). Environmental exposure to cadmium and risk of cancer: a prospective population-based study. *The Lancet Oncology*, **7(2)**: 119-126.

OECD (2014). *The Cost of Air Pollution: Health Impacts of Road Transport*. Paris: Organisation for Economic Cooperation and Development Publishing. https://read.oecd-ilibrary.org/environment/the-cost-of-air-pollution_97892642104 48-en#page1.

OECD (2016). *The Economic Consequences of Outdoor Air Pollution*. Paris: Organisation for Economic Cooperation and Development Publishing. https://read.oecd-ilibrary.org/ environment/the-economic-consequences-of-outdoor-air-pollution_9789264257474-en#page1.

OECD (2017). Measuring distance to the SDG targets: An assessment of where OECD countries stand. OECD. http://www.oecd.org/std/OECD-Measuring-Distance-to-SDG-Targets.pdf. (accessed on 27/6/2021). *O'Neill, B. C., Kriegler*

Penard-Morand, C., Charpin, D., Raherison, C., Kopferschmitt, C., Callaud, D., Lavaud, F., et al. (2005). Long-term exposure to background air pollution related to respiratory and allergic health in schoolchildren. *Clinical Experimental Allergy*, **35(10)**: 1279-1287.

Pino, P., Walter, T., Oyarzun, M., Villegas, R. and Romieu, I. (2004). Fine particulate matter and wheezing illnesses in the first year of life. *Epidemiology*, **15(6)**: 702-708.

Rastogi, S.K., Gupta, B.N., Husain, T., Chandra, H., Mathur, N., Pangtey, B.S., Chandra, S.V. and Garg, N. (1991). A cross-sectional study of pulmonary function among workers exposed to multimetals in the glass bangle industry, *American Journal of industrial medicine*, **20(3)**: 391-399.

Ratnaike, R.N. (2003). Acute and chronic arsenic toxicity. *Postgraduate Medical Journal*, **79(933)**: 391-396.

Ritchie, H., and Roser, M. (2017). *Air pollution. Our World in Data.* https://ourworldindata.org/ air-pollution#note-15

Sachs, J., Schmidt-Traub, G., Kroll, C., Lafortune, G., & Fuller, G. (2018). SDG index and dashboards report 2018. *New York: Bertelsmann Stifung and Sustainable Development Solutions Network (SDSN).*

Sagiv SK, Mendola P, Loomis D, Herring AH, Neas LM, Savitz DA, et al. (2005). A time-series analysis of air pollution and preterm birth in Pennsylvania, 1997–2001. *Environmental Health Perspectives*, *113(5)*: 602-606.

Seiford, L. M., & Zhu, J. (1999). Profitability and marketability of the top 55 US commercial banks. *Management Science, 45(9)*, 1270–1288.

Shahroudi, K., Mohammadi, G., & Taleghani, M. (2011). Application of Two-Stage DEA Technique for Efficiencies Measuring of Private Insurance Companies in Iran. *International Journal of Applied Operational Research, 1(3)*, 91-105.

Simar, L. and Wilson, P.W. (1998). Sensitivity analysis of efficiency scores: how to bootstrap in nonparametric frontier models. *Management Science*, **44(1)**: 49-61.

Tager, I.B., Balmes, J., Lurmann, F., Ngo, L., Alcorn, S. and Kunzli, N. (2005). Chronic exposure to ambient ozone and lung function in young adults. *Epidemiology*, **16(6)**: 751-759.

Thomke, F., Jung, D., Besser, R., Roder, R., Konietzko, J. and Hopf, H.C. (1999). Increased risk of sensory neuropathy in workers with chloracne after exposure to 2,3,7,8-polychlorinated dioxins and furans, *Acta neurologica Scandinavica*, **100(1)**: 1-5.

Uysal, N., Schapira, R.M. (2003). Effects of ozone on lung function and lung diseases. *Current opinion in pulmonary medicine*, **9(2)**: 144-150.

Vamvakas, S., Bittner, D. and Koster, U. (1993). Enhanced expression of the protooncogenes c-myc and c-fos in normal and malignant renal growth. *Toxicology Letters*, **67(1-3)**: 161-172.

Varabyova Y. and Müller J.M. (2016). The efficiency of health care production in OECD countries: A systematic review and meta-analysis of cross-country comparisons. Health Policy*, **120(3):** 252-263.*

Vineis, P., Forastiere, F., Hoek, G. and Lipsett, M. (2004). Outdoor air pollution and lung cancer: recent epidemiological evidence. *International Journal of Cancer*, **111(5)**: 647-652.

Walkowiak, J., Wiener, J.A., Fastabend, A., Heinzow, B., Kramer, U., Schmidt, E., Steingruber, H.J., Wundram, S. and Winneke, G. (2001). Environmental exposure to polychlorinated biphenyls and quality of the home environment: effects on psychodevelopment in early childhood. *The Lancet*, **358(9293)**: 1602-1607.

Wang, C.H., Gopal, R.D. & Zionts, S. (1997). Use of Data Envelopment Analysis in assessing Information Technology impact on firm performance. *Annals of Operations Research, 73*, 191–213.

Ward M., Currie L.M., Kabir A. and Clancy L. (2013). The efficacy of different models of smoke-free laws in reducing exposure to second-hand smoke: A multi-country comparison. *Health Policy*, **110(2-3):** 207-213.

WHO (2002). Global defense against the infectious disease threat. In Emerging and Epidemic-Prone Diseases, ed. MK Kindhauser. *Geneva, Switzerland: World Health Organization*. pp. 56–103

WHO/UN Child. Fund (UNICEF) (2008). Progress on Drinking-Water and Sanitation: Special Focus on Sanitation. *Geneva, Switzerland /New York: WHO/UNICEF*. 58 pp.

WHO (2009). Global Health Risks: Mortality and Burden of Disease Attributable to Selected Major Risks. *Geneva, Switzerland: World Health Organization*

WHO. (2015). Economic cost of the health impact of air pollution in Europe: Clean air, health and wealth. http://www.euro.who.int/en/media-centre/events/events/2015/ 04/ehp-mid-term-review/publications/economic-cost-of-the-health-impact-of-air-pollution-in-europe.

WHO (2016). Dioxins and their effects on human health. https://www.who.int/news-room/fact-sheets/detail/dioxins-and-their-effects-on-human-health

Ye, F., Piver, W.T., Ando, M. and Portier, C.J. (2001). Effects of temperature and air pollutants on cardiovascular and respiratory diseases for males and females older than 65 years of age in Toyko, July and August 1980–1995. *Environmental Health Perspectives*, **109(4)**: 355-359.

Zha, Y., & Liang, L. (2010). Two-stage cooperation model with input freely distributed among the stages. *European Journal of Operational Research, 205(2),* 332-338.

Appendix

Table A1: Efficiency scores per country and per year

Years	1990			1991			1992			1993		
Countries	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2
Australia	0.373657650	0.397215093	0.940693486	0.383290785	0.402832057	0.951490278	0.389057508	0.404530913	0.961749758	0.377003104	0.387128183	0.973845669
Austria	0.679941516	0.744814907	0.912899983	0.662244522	0.742293471	0.892159971	0.694590469	0.784122521	0.885818798	0.697419050	0.795797698	0.876377315
Belgium	0.474915653	0.532678693	0.891561197	0.465537335	0.517275615	0.899979279	0.462198383	0.510654001	0.905110667	0.476619406	0.525496976	0.906987913
Canada	0.231867400	0.231867400	**1.000000000**	0.236428660	0.236428660	**1.000000000**	0.241032111	0.241032111	**1.000000000**	0.236516761	0.236516761	**1.000000000**
Denmark	0.702659508	0.768714859	0.914070412	0.656185948	0.709819096	0.924441104	0.680004549	0.733598126	0.926944229	0.674445160	0.727237595	0.927406896
Finland	0.520387852	0.556335530	0.935384895	0.526661800	0.559807060	0.940791637	0.542513977	0.574480249	0.944356187	0.541263525	0.572245744	0.945858542
France	0.317467387	0.416671818	0.761912308	0.312897160	0.398801292	0.784594147	0.346786705	0.438372439	0.791077802	0.342005855	0.428682756	0.797806419
Germany	0.218291804	0.284943119	0.766089051	0.235743214	0.323391363	0.728971893	0.268051510	0.369631406	0.725185973	0.276294275	0.375563167	0.735679906
Greece	0.845407675	0.909343047	0.929690591	0.859529803	0.916248855	0.938096455	0.879415105	0.930521120	0.945078070	0.886996723	0.934684593	0.948979720
Iceland	0.936263389	**1.000000000**	0.936263389	0.942922395	**1.000000000**	0.942922395	0.948470576	**1.000000000**	0.948470576	0.950339163	**1.000000000**	0.950339163
Ireland	0.921965110	**1.000000000**	0.921965110	0.929671960	**1.000000000**	0.929671960	0.934841343	**1.000000000**	0.934841343	0.937109671	**1.000000000**	0.937109671
Italy	0.471904586	0.604486111	0.780670684	0.473504364	0.599993071	0.789183053	0.519123132	0.648193100	0.800877289	0.523662551	0.643272952	0.814059645
Japan	0.298067326	0.452100903	0.659293809	0.303470613	0.454287462	0.668014504	0.319258446	0.476065095	0.670619311	0.319273953	0.466444590	0.684484203
Luxembourg	0.928374355	0.993180258	0.934749103	0.809873297	0.860192980	0.941501868	0.805434307	0.850607967	0.946892503	0.842682417	0.888121826	0.948836514
Netherlands	0.430694636	0.490076809	0.878830886	0.421166855	0.475355535	0.886003892	0.434913951	0.487974729	0.891263267	0.432229848	0.484511989	0.892093194
New Zealand	0.855872444	0.926589745	0.923680031	0.868838870	0.933423611	0.930808756	0.866610572	0.925646310	0.936222143	0.865191983	0.921876672	0.938511636
Norway	0.604612866	0.654543287	0.923717160	0.602040467	0.647195064	0.930230314	0.596099936	0.637550695	0.934984372	0.587459993	0.626963943	0.936991672
Portugal	0.905154163	**1.000000000**	0.905154163	0.912376668	**1.000000000**	0.912376668	0.922283725	**1.000000000**	0.922283725	0.923072578	**1.000000000**	0.923072578
Spain	0.537256578	0.665000208	0.807904377	0.530954102	0.648230744	0.819081951	0.567078722	0.682916244	0.830378142	0.590435249	0.705788486	0.836561180
Sweden	0.437274762	0.477423409	0.915905575	0.433283648	0.469784411	0.922303163	0.450977470	0.486177696	0.927598023	0.457828947	0.492605521	0.929402793
Switzerland	0.624055534	0.682871541	0.913869589	0.630061778	0.684130410	0.920967361	0.636484230	0.686691918	0.926884697	0.656892199	0.706549268	0.929718887
United Kingdom	0.277472978	0.389247315	0.712844938	0.280192144	0.383585818	0.730454909	0.307746115	0.412992695	0.745161158	0.305875385	0.409703831	0.746576825
United States	0.000002111	0.000010636	0.198452822	0.000002080	0.000011173	0.186197061	0.000002156	0.000012022	0.179327683	0.000001985	0.000011926	0.166415562

Table A1: Efficiency scores per country and per year

Years	1994			1995			1996			1997		
Countries	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2
Australia	0.387953227	0.393503334	0.985895654	0.391592201	0.404691159	0.967632210	0.381718753	0.392656404	0.972144474	0.394382414	0.401333925	0.982678983
Austria	0.728790194	0.839633200	0.867986394	0.703659427	0.957309979	0.735038224	0.690215705	0.953767054	0.723673252	0.726500189	0.971409813	0.747882283
Belgium	0.475514701	0.519619338	0.915121256	0.461485348	0.519240111	0.888770606	0.460642151	0.519257775	0.887116522	0.483779556	0.541380309	0.893603901
Canada	0.239052422	0.239052422	**1.000000000**	0.241487430	0.241487430	**1.000000000**	0.240725811	0.240725811	**1.000000000**	0.250331800	0.250331800	**1.000000000**
Denmark	0.687516492	0.734547199	0.935973199	0.684245360	0.753066519	0.908612112	0.645870642	0.711461791	0.907807910	0.722547189	0.793424512	0.910669103
Finland	0.546303272	0.572181902	0.954772023	0.537779569	0.580753426	0.926003265	0.537910017	0.582413269	0.923588190	0.543731169	0.584890100	0.929629632
France	0.371986404	0.458509803	0.811294331	0.388214106	0.486546416	0.797897371	0.363191642	0.454379657	0.799313166	0.400939717	0.498644881	0.804058623
Germany	0.292473735	0.397151339	0.736428929	0.315470512	0.446994865	0.705758693	0.303569219	0.433347738	0.700521066	0.331911014	0.467786059	0.709535924
Greece	0.898824262	0.936472406	0.959797914	0.916060295	0.979882115	0.934867859	0.901879084	0.966778892	0.932870062	0.924801405	0.982404138	0.941365544
Iceland	0.959197344	**1.000000000**	0.959197344	0.930651607	**1.000000000**	0.930651607	0.928121874	**1.000000000**	0.928121874	0.934997051	**1.000000000**	0.934997051
Ireland	0.947738470	**1.000000000**	0.947738470	0.920037663	**1.000000000**	0.920037663	0.917512465	**1.000000000**	0.917512465	0.925575966	**1.000000000**	0.925575966
Italy	0.550489357	0.668081810	0.823984950	0.549076847	0.676242145	0.811953013	0.541208633	0.669590424	0.808268180	0.565763121	0.697616506	0.810994459
Japan	0.319783109	0.451740550	0.707891087	0.337253156	0.484656505	0.695860166	0.331674625	0.468779723	0.707527670	0.352269724	0.487625549	0.722418513
Luxembourg	0.894377852	0.933877179	0.957703938	0.928933969	**1.000000000**	0.928933969	0.926261670	**1.000000000**	0.926261670	0.933065968	**1.000000000**	0.933065968
Netherlands	0.444708895	0.492859592	0.902303419	0.427808811	0.488418685	0.875905907	0.417195497	0.478142932	0.872533021	0.444631513	0.505537470	0.879522369
New Zealand	0.876342150	0.924627146	0.947778954	0.849427442	0.923719241	0.919573183	0.860468983	0.938710175	0.916650321	0.868214864	0.939516111	0.924108542
Norway	0.605083227	0.639629583	0.945990059	0.576500418	0.628113706	0.917828114	0.598035786	0.653635420	0.914937850	0.597820602	0.648782881	0.921449408
Portugal	0.933938004	**1.000000000**	0.933938004	0.909807157	**1.000000000**	0.909807157	0.903062812	**1.000000000**	0.903062812	0.910794506	**1.000000000**	0.910794506
Spain	0.581610546	0.687234651	0.846305618	0.599108907	0.724990232	0.826368247	0.595867555	0.735772807	0.809852646	0.596966263	0.727635926	0.820418897
Sweden	0.456669994	0.486319888	0.939032117	0.445915890	0.489592243	0.910790350	0.454987506	0.501188051	0.907817945	0.487508291	0.533392999	0.913975797
Switzerland	0.683520469	0.728268585	0.938555476	0.691074419	0.758737265	0.910821770	0.699803425	0.769994568	0.908842029	0.724142946	0.791041501	0.915429779
United Kingdom	0.322588954	0.426723903	0.755966451	0.348879768	0.470746965	0.741119526	0.332100621	0.455044155	0.729820649	0.365732055	0.506409761	0.722205777
United States	0.000001966	0.000012361	0.159015197	0.000002023	0.000015670	0.129113589	0.000001916	0.000015446	0.124050236	0.000001973	0.000015838	0.124595223

Table A1: Efficiency scores per country and per year

Years	1998			1999			2000			2001		
Countries	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2
Australia	0.411357012	0.418511556	0.982904787	0.399395773	0.402625847	0.991977480	0.369408781	0.369408781	**1.000000000**	0.376033790	0.376033790	**1.000000000**
Austria	0.754172623	**1.000000000**	0.754172623	0.689102456	**1.000000000**	0.689102456	0.614432645	**1.000000000**	0.614432645	0.584269753	**1.000000000**	0.584269753
Belgium	0.502620232	0.560142958	0.897307062	0.493044962	0.554220165	0.889619313	0.461684167	0.540567487	0.854073133	0.458544601	0.550338399	0.833204809
Canada	0.264555153	0.264555153	**1.000000000**	0.261560647	0.261560647	**1.000000000**	0.242800950	0.249582913	0.972826812	0.243770639	0.256173061	0.951585769
Denmark	0.771878958	0.845775151	0.912629033	0.786015127	0.871209870	0.902210999	0.758012186	0.877294498	0.864033899	0.736896740	0.875377716	0.841804317
Finland	0.561404917	0.602626819	0.931596303	0.577761559	0.626170993	0.922689754	0.566500723	0.641264451	0.883412019	0.558328313	0.648199559	0.861352504
France	0.425010339	0.523175654	0.812366431	0.460308458	0.565413784	0.814109013	0.447648980	0.565021577	0.792268823	0.428555150	0.551855642	0.776571112
Germany	0.370777040	0.515492305	0.719267846	0.409684187	0.568465167	0.720684767	0.394110798	0.569954983	0.691477063	0.378789728	0.554240409	0.683439391
Greece	0.927023373	0.981118455	0.944863863	0.936992068	**1.000000000**	0.936992068	0.852826477	0.946716616	0.900825509	0.815910218	0.928740170	0.878512898
Iceland	0.937418070	**1.000000000**	0.937418070	0.928388495	**1.000000000**	0.928388495	0.889494008	**1.000000000**	0.889494008	0.866606067	**1.000000000**	0.866606067
Ireland	0.929305117	**1.000000000**	0.929305117	0.920409716	**1.000000000**	0.920409716	0.881979754	**1.000000000**	0.881979754	0.860300576	**1.000000000**	0.860300576
Italy	0.596101200	0.738197717	0.807508864	0.628643160	0.778926621	0.807063391	0.594774511	0.768621166	0.773820104	0.580141481	0.767973786	0.755418337
Japan	0.390249220	0.539747287	0.723022105	0.411334190	0.565309588	0.727626417	0.392403657	0.551760326	0.711184981	0.391818393	0.561019880	0.698403759
Luxembourg	0.935443940	**1.000000000**	0.935443940	0.925928469	**1.000000000**	0.925928469	0.886683199	**1.000000000**	0.886683199	0.863682583	**1.000000000**	0.863682583
Netherlands	0.466524512	0.528819949	0.882199155	0.458476171	0.523940382	0.875054085	0.434812039	0.518869299	0.837999165	0.420040265	0.513560772	0.817897876
New Zealand	0.901461973	0.972150963	0.927285994	0.903203376	0.983523434	0.918334373	0.879971053	0.999354522	0.880539422	0.857931174	**1.000000000**	0.857931174
Norway	0.605899552	0.656046576	0.923561793	0.609493867	0.666565277	0.914379863	0.602947187	0.688721087	0.875459164	0.594634613	0.697265458	0.852809509
Portugal	0.916196557	**1.000000000**	0.916196557	0.909384544	**1.000000000**	0.909384544	0.871151649	**1.000000000**	0.871151649	0.847859750	**1.000000000**	0.847859750
Spain	0.614156356	0.756454054	0.811888512	0.622454525	0.767885778	0.810608222	0.578971033	0.735947093	0.786701977	0.556412717	0.723350288	0.769216140
Sweden	0.506237108	0.552617705	0.916071099	0.493627266	0.544464339	0.906629195	0.469976632	0.541209877	0.868381478	0.442666166	0.523444300	0.845679600
Switzerland	0.755505636	0.822554005	0.918487578	0.695286542	0.763940820	0.910131418	0.630514911	0.723176414	0.871868744	0.597798159	0.703159544	0.850160058
United Kingdom	0.396510247	0.543260229	0.729871663	0.425851855	0.591798198	0.719589645	0.412613042	0.588431241	0.701208592	0.404428549	0.590851117	0.684484699
United States	0.000002062	0.000017033	0.121033866	0.000002042	0.000019442	0.105008976	0.000001868	0.000020508	0.091095738	0.000001829	0.000021615	0.084630539

Table A1: Efficiency scores per country and per year

Years	2002			2003			2004			2005		
Countries	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2
Australia	0.349878721	0.349878721	**1.000000000**	0.351855038	0.351855038	**1.000000000**	0.362081959	0.362081959	**1.000000000**	0.371831319	0.371831319	**1.000000000**
Austria	0.532598333	**1.000000000**	0.532598333	0.521588455	**1.000000000**	0.521588455	0.523812032	**1.000000000**	0.523812032	0.522489358	**1.000000000**	0.522489358
Belgium	0.444676185	0.550448178	0.807843868	0.431770967	0.536940733	0.804131518	0.444305672	0.540147710	0.822563279	0.448671817	0.546569374	0.820887225
Canada	0.236080884	0.253942785	0.929661710	0.225490128	0.244695605	0.921512786	0.231148477	0.244912752	0.943799268	0.236666487	0.253989760	0.931795387
Denmark	0.704330652	0.863066600	0.816079144	0.675871012	0.831207428	0.813119553	0.712421359	0.858062058	0.830267872	0.730209272	0.880782636	0.829045944
Finland	0.528887808	0.633267627	0.835172660	0.513534992	0.617414606	0.831750638	0.540151366	0.637094391	0.847835696	0.568052519	0.672629866	0.844524676
France	0.421511824	0.557377938	0.756240596	0.413958598	0.548804737	0.754291226	0.434171402	0.559707529	0.775711206	0.445980455	0.575395852	0.775084584
Germany	0.379208457	0.571663385	0.663342217	0.378205415	0.572299081	0.660852739	0.396742549	0.584684603	0.678558230	0.410667337	0.603114063	0.680911560
Greece	0.772981361	0.906614774	0.852601771	0.754617298	0.889327385	0.848525875	0.767399032	0.886824625	0.865333473	0.769774108	0.891038031	0.863907130
Iceland	0.840147101	**1.000000000**	0.840147101	0.835490095	**1.000000000**	0.835490095	0.852435090	**1.000000000**	0.852435090	0.850409396	**1.000000000**	0.850409396
Ireland	0.832681227	**1.000000000**	0.832681227	0.827428602	**1.000000000**	0.827428602	0.844183215	**1.000000000**	0.844183215	0.842369011	**1.000000000**	0.842369011
Italy	0.561743924	0.769581413	0.729934371	0.529026183	0.738311264	0.716535436	0.558186075	0.759172074	0.735256333	0.562762410	0.770445339	0.730437816
Japan	0.384720108	0.563276446	0.683004074	0.382063899	0.565771228	0.675297506	0.385587279	0.563499115	0.684273088	0.393148411	0.580814508	0.676891513
Luxembourg	0.836914704	**1.000000000**	0.836914704	0.832473380	**1.000000000**	0.832473380	0.849633175	**1.000000000**	0.849633175	0.847249775	**1.000000000**	0.847249775
Netherlands	0.396664852	0.500162672	0.793071683	0.387840053	0.491512195	0.789075137	0.395803113	0.490705914	0.806599434	0.411437673	0.510771641	0.805521764
New Zealand	0.831840571	**1.000000000**	0.831840571	0.828485596	**1.000000000**	0.828485596	0.845577922	**1.000000000**	0.845577922	0.844184447	**1.000000000**	0.844184447
Norway	0.602396410	0.729000001	0.826332523	0.580981019	0.706573073	0.822251854	0.618767550	0.737319074	0.839212727	0.624848146	0.746568690	0.836960021
Portugal	0.821833801	**1.000000000**	0.821833801	0.811878915	**1.000000000**	0.811878915	0.830063817	**1.000000000**	0.830063817	0.828428701	**1.000000000**	0.828428701
Spain	0.532582770	0.702848006	0.757749564	0.516251386	0.700964553	0.736487150	0.528902178	0.698403096	0.757302167	0.539132269	0.714122677	0.754957498
Sweden	0.408219180	0.498057231	0.819623036	0.410694078	0.503627140	0.815472490	0.413111166	0.496892269	0.831389803	0.420845391	0.507374516	0.829457092
Switzerland	0.567462100	0.688656064	0.824013800	0.584226235	0.712690879	0.819747035	0.596350946	0.712443462	0.837050206	0.614024835	0.735312703	0.835052669
United Kingdom	0.403131303	0.611919165	0.658798296	0.392918795	0.601150015	0.653611885	0.418784776	0.630470837	0.664241312	0.432438817	0.652715608	0.662522561
United States	0.000001741	0.000023027	0.075599305	0.000001702	0.000023380	0.072799025	0.000001767	0.000024119	0.073250346	0.000001751	0.000024783	0.070652564

Table A1: Efficiency scores per country and per year

Years	2006			2007			2008			2009		
Countries	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2
Australia	0.320378951	0.320378951	**1.000000000**	0.266052014	0.266052014	**1.000000000**	0.219581956	0.219581956	**1.000000000**	0.172980605	0.172980605	**1.000000000**
Austria	0.461420181	**1.000000000**	0.461420181	0.400502094	**1.000000000**	0.400502094	0.336416040	**1.000000000**	0.336416040	0.275648843	**1.000000000**	0.275648843
Belgium	0.423862684	0.526461394	0.805116366	0.387174388	0.493557575	0.784456379	0.336608426	0.450576637	0.747061429	0.278789382	0.400704100	0.695748763
Canada	0.214254329	0.234595959	0.913290794	0.183481457	0.202849217	0.904521399	0.154855896	0.178478226	0.867645870	0.125693351	0.156500151	0.803151626
Denmark	0.658932049	0.811971950	0.811520705	0.604726412	0.765127602	0.790360210	0.537752624	0.713444325	0.753741540	0.446924683	0.636684653	0.701956112
Finland	0.538070984	0.649861078	0.827978474	0.502810342	0.623047326	0.807017896	0.461592874	0.600332533	0.768895318	0.393180451	0.548737025	0.716518903
France	0.405249329	0.532260909	0.761373457	0.353151826	0.474239584	0.744669650	0.297884127	0.419951186	0.709330362	0.241216392	0.365994877	0.659070405
Germany	0.353903591	0.528364948	0.669808988	0.318314835	0.487692251	0.652696109	0.264133782	0.422936727	0.624523162	0.214823069	0.373212732	0.575604879
Greece	0.682336981	0.807667838	0.844823761	0.583303272	0.708323148	0.823498813	0.489208423	0.623820710	0.784213180	0.390630657	0.536807488	0.727692265
Iceland	0.832549959	**1.000000000**	0.832549959	0.812775501	**1.000000000**	0.812775501	0.776762564	**1.000000000**	0.776762564	0.724279778	**1.000000000**	0.724279778
Ireland	0.824224660	**1.000000000**	0.824224660	0.748250653	0.931638497	0.803155575	0.667441946	0.871976539	0.765435669	0.550118680	0.772002298	0.712586843
Italy	0.504205512	0.704701561	0.715488002	0.434463203	0.623904634	0.696361558	0.373830123	0.563023044	0.663969489	0.310073671	0.502879437	0.616596441
Japan	0.349101263	0.524017262	0.666201838	0.300234756	0.461844578	0.650077472	0.263213914	0.422038246	0.623673130	0.212537087	0.364432692	0.583199839
Luxembourg	0.829226450	**1.000000000**	0.829226450	0.807778145	**1.000000000**	0.807778145	0.769914171	**1.000000000**	0.769914171	0.717558162	**1.000000000**	0.717558162
Netherlands	0.368714610	0.467154211	0.789278146	0.316714264	0.411411472	0.769823607	0.270158680	0.368056631	0.734013891	0.214255743	0.313282426	0.683906039
New Zealand	0.826559401	**1.000000000**	0.826559401	0.805273954	**1.000000000**	0.805273954	0.768204815	0.999088569	0.768905619	0.638768253	0.891426228	0.716568834
Norway	0.584720250	0.713988947	0.818948602	0.510458862	0.640082331	0.797489382	0.412279194	0.542218239	0.760356559	0.346631830	0.489351669	0.708349132
Portugal	0.810450074	**1.000000000**	0.810450074	0.753764004	0.954255742	0.789897268	0.648404703	0.863469836	0.750929188	0.529329659	0.758267452	0.698077778
Spain	0.489970417	0.658712058	0.743830951	0.420132913	0.575638042	0.729856059	0.373579241	0.568514611	0.657114582	0.317700967	0.520259505	0.610658650
Sweden	0.383125987	0.471926635	0.811833785	0.333034242	0.421187268	0.790703487	0.281679878	0.373565309	0.754031148	0.234147737	0.333115197	0.702903196
Switzerland	0.521930117	0.638573183	0.817337982	0.473715987	0.594938195	0.796244032	0.388812044	0.512051968	0.759321452	0.301603361	0.426346243	0.707414141
United Kingdom	0.392230121	0.603447689	0.649981974	0.352021032	0.554937417	0.634343659	0.304467909	0.503360409	0.604870593	0.253084892	0.447564371	0.565471491
United States	0.000001567	0.000025354	0.061791257	0.000001312	0.000024787	0.052949340	0.000001112	0.000025757	0.043187845	0.000000900	0.000025739	0.034973823

Table A1: Efficiency scores per country and per year

Years	2010			2011			2012			2013		
Countries	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2
Australia	0.152909802	0.152909802	**1.000000000**	0.107199967	0.107199967	**1.000000000**	0.066778747	0.066778747	**1.000000000**	0.065851985	0.065851985	**1.000000000**
Austria	0.225987762	**1.000000000**	0.225987762	0.162465762	**1.000000000**	0.162465762	0.099108848	**1.000000000**	0.099108848	0.095101916	**1.000000000**	0.095101916
Belgium	0.231983184	0.345510038	0.671422415	0.170701007	0.294307034	0.580009946	0.106024027	0.233706519	0.453663111	0.102063631	0.224718757	0.454183854
Canada	0.110034397	0.139307595	0.789866460	0.075457023	0.107298933	0.703241132	0.046587354	0.078595702	0.592746838	0.045054276	0.074921487	0.601353192
Denmark	0.375354416	0.554086160	0.677429690	0.278982979	0.476887920	0.585007435	0.174671977	0.381936217	0.457332847	0.168794034	0.368677005	0.457837162
Finland	0.334530333	0.482833479	0.692848254	0.253571764	0.423915290	0.598166120	0.164195080	0.351087148	0.467676133	0.159575100	0.340982159	0.467986653
France	0.205337826	0.321894809	0.637903500	0.149541289	0.269973063	0.553911888	0.090731752	0.207615878	0.437017406	0.088097730	0.201516640	0.437173476
Germany	0.176693093	0.317149831	0.557128131	0.127698711	0.261532571	0.488270773	0.077207678	0.198805926	0.388357026	0.073186255	0.188856921	0.387522227
Greece	0.364044741	0.526658563	0.691234828	0.260666533	0.439756089	0.592752526	0.157726408	0.340481536	0.463245114	0.172613002	0.372522059	0.463363169
Iceland	0.700335971	**1.000000000**	0.700335971	0.606086007	**1.000000000**	0.606086007	0.475672755	**1.000000000**	0.475672755	0.474759661	**1.000000000**	0.474759661
Ireland	0.466994802	0.678886809	0.687883158	0.346951971	0.584718381	0.593365938	0.214493532	0.462519908	0.463749837	0.206639044	0.445183390	0.464166113
Italy	0.266085315	0.445174912	0.597709590	0.192112876	0.371039137	0.517769842	0.121558978	0.298030996	0.407873609	0.124407665	0.304351416	0.408763219
Japan	0.173648080	0.307544306	0.564627850	0.129923709	0.263021830	0.493965495	0.080374383	0.199564726	0.402748447	0.077252683	0.190168345	0.406233135
Luxembourg	0.692275262	**1.000000000**	0.692275262	0.597063517	**1.000000000**	0.597063517	0.466421942	**1.000000000**	0.466421942	0.466726106	**1.000000000**	0.466726106
Netherlands	0.175951915	0.266690233	0.659761376	0.132741918	0.232897535	0.569958452	0.080035965	0.179543417	0.445774990	0.078284987	0.175407503	0.446303525
New Zealand	0.552229415	0.797481399	0.692466829	0.413467514	0.690656308	0.598658854	0.262093579	0.557877417	0.469804962	0.249504898	0.530532666	0.470291302
Norway	0.294328096	0.430417673	0.683819729	0.229347528	0.388712954	0.590017713	0.142359703	0.308456614	0.461522616	0.133530925	0.289068036	0.461935975
Portugal	0.443099860	0.657622328	0.673790779	0.323200553	0.554852037	0.582498633	0.202558566	0.444281605	0.455923819	0.198660971	0.435306242	0.456370600
Spain	0.279808069	0.473837118	0.590515303	0.198697354	0.384292005	0.517047848	0.120231704	0.293879996	0.409118366	0.125126942	0.306928235	0.407674913
Sweden	0.190095503	0.280053607	0.678782556	0.136722896	0.233422903	0.585730423	0.083838596	0.183027652	0.458065187	0.080232322	0.175051989	0.458334248
Switzerland	0.274249786	0.401756465	0.682626939	0.199359590	0.338397309	0.589128769	0.120591967	0.261931275	0.460395450	0.113088273	0.245458017	0.460723487
United Kingdom	0.215187765	0.389970039	0.551805891	0.163983801	0.339299766	0.483300661	0.096754926	0.248185143	0.389849792	0.095180429	0.247092975	0.385200870
United States	0.000000770	0.000027054	0.028447704	0.000000527	0.000026679	0.019761718	0.000000321	0.000027047	0.011861967	0.000000302	0.000027139	0.011118174

Table A1: Efficiency scores per country and per year

Years	2014			2015			2016			2017		
Countries	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2	E_p	E_p^1	E_p^2
Australia	0.056605520	0.056605520	**1.000000000**	0.029615316	0.029615316	**1.000000000**	0.005232752	0.005232752	**1.000000000**	0.006745669	0.006745669	**1.000000000**
Austria	0.083219286	**1.000000000**	0.083219286	0.044357628	**1.000000000**	0.044357628	0.007815803	**1.000000000**	0.007815803	0.010023758	**1.000000000**	0.010023758
Belgium	0.089737833	0.217259720	0.413044041	0.048226368	0.171520915	0.281169021	0.008555235	0.137649851	0.062152157	0.010980029	0.130781260	0.083957208
Canada	0.037076148	0.067968749	0.545488166	0.020639935	0.052846063	0.390567128	0.003781203	0.039087261	0.096737468	0.004883714	0.038423504	0.127102261
Denmark	0.149098415	0.358611213	0.415766182	0.080394237	0.284558544	0.282522660	0.014228218	0.228441792	0.062283778	0.018198364	0.216331691	0.084122507
Finland	0.139892380	0.329429723	0.424650147	0.078911096	0.272940254	0.289114908	0.014449334	0.226361350	0.063833043	0.018646471	0.216565894	0.086100680
France	0.077860217	0.196949255	0.395331360	0.041529832	0.153492865	0.270565226	0.007553649	0.125863533	0.060014599	0.009884763	0.121634760	0.081265940
Germany	0.064496460	0.182455908	0.353490666	0.034017597	0.139783261	0.243359593	0.006083749	0.111315203	0.054653356	0.007985352	0.106485471	0.074990063
Greece	0.145536869	0.346413006	0.420125303	0.076239862	0.266164209	0.286439197	0.014138385	0.224660604	0.062932195	0.017834641	0.208865565	0.085388135
Iceland	0.430728618	**1.000000000**	0.430728618	0.293245806	**1.000000000**	0.293245806	0.064674075	**1.000000000**	0.064674075	0.087351134	**1.000000000**	0.087351134
Ireland	0.179557439	0.426555836	0.420947093	0.097081156	0.339411778	0.286027657	0.016618144	0.263575390	0.063048922	0.020956336	0.246146641	0.085137608
Italy	0.112063753	0.301556135	0.371618217	0.058434128	0.231030945	0.252927711	0.011151068	0.197447074	0.056476239	0.014950547	0.195241919	0.076574473
Japan	0.066983054	0.179970967	0.372188112	0.036664446	0.136635376	0.268337874	0.006264411	0.099113729	0.063204276	0.008684804	0.100473371	0.086438866
Luxembourg	0.423778333	**1.000000000**	0.423778333	0.287756286	**1.000000000**	0.287756286	0.063384063	**1.000000000**	0.063384063	0.085588087	**1.000000000**	0.085588087
Netherlands	0.070042566	0.172561280	0.405899664	0.038480836	0.139480456	0.275886935	0.006921107	0.113769843	0.060834285	0.009134171	0.111203410	0.082139306
New Zealand	0.212868588	0.498456007	0.427055918	0.118016231	0.404730744	0.291591960	0.021218369	0.329201601	0.064454028	0.026827555	0.307279536	0.087306677
Norway	0.119271702	0.284167302	0.419723525	0.064559518	0.226170189	0.285446631	0.011758805	0.186799401	0.062948838	0.015196809	0.178748584	0.085017786
Portugal	0.177046833	0.427171716	0.414462910	0.096427434	0.341145808	0.282657537	0.017417646	0.278859790	0.062460227	0.022730303	0.269174591	0.084444462
Spain	0.107076202	0.287263021	0.372746207	0.054832722	0.213416742	0.256927932	0.009723778	0.169963094	0.057211114	0.012697058	0.162778519	0.078002050
Sweden	0.069889691	0.167973588	0.416075478	0.037182546	0.131498539	0.282760149	0.006613611	0.106003393	0.062390559	0.008417643	0.099866392	0.084289042
Switzerland	0.102626322	0.245252251	0.418452111	0.057110148	0.200991377	0.284142278	0.010216433	0.163106663	0.062636515	0.013611852	0.160874140	0.084611809
United Kingdom	0.086837251	0.249887428	0.347505483	0.046807515	0.199222304	0.234951175	0.008607455	0.167710038	0.051323432	0.011523858	0.164807838	0.069922997
United States	0.000000247	0.000025855	0.009564452	0.000000133	0.000026710	0.004981177	0.000000023	0.000027152	0.000863251	0.000000030	0.000027632	0.001082777

LISTS OF PARTICIPANTS

PARTICIPATING BODIES Academic and Research Institutions & Organizations	
1	Agricultural University of Athens
2	Aristotle University of Thessaloniki
3	Athens University of Economics and Business
4	Burgundy School of Business
5	Conservatoire of the Municipality of Kalamaria
6	Democritus University of Thrace
7	Greek Ministry of Education and Religious Affairs
8	Harokopio University
9	Hellenic Open University
10	Hellinikos Georgikos Organismos DIMITRA
11	Institute for Global Sustainable Development
12	International Hellenic University
13	Ionian University
14	Model Dance School of the Municipality of Kalamaria
15	Politecnico di Milano
16	Primary Education of Western Thessaloniki
17	Public Experimental Vocational Training Institute of Patras
18	Technical University of Crete
19	University of Ioannina
20	University of Macedonia
21	University of Patras
22	University of the Aegean
23	University of Thessaly
24	University of Warwick
25	University of West Attica
26	Vocational School (EPAL) of Edessa

Academic and Research Participants		
No	**Full Name**	**University/Organization**
1	Adamidis Theodoros	Aristotle University of Thessaloniki
2	Arabatzis Garyfallos	Democritus University of Thrace
3	Argyropoulou Georgia	University of Thessaly
4	Bampatsou Christina	University of Thessaly
5	Boemi Sofia-Natalia	Ionian University
6	Botzoris George	Democritus University of Thrace
7	Botzoris Nikiforos	Democritus University of Thrace
8	Chatzistamoulou Nikos	Democritus University of Thrace
9	Christopoulou Olga	University of Ioannina, University of Patras
10	Coutelieris Frank A.	University of Patras
11	Dimoudi Argyro	Democritus University of Thrace
12	Dritsas Sophocles E.	University of Thessaly
13	Economou Emmanuil Marios	University of Thessaly
14	Economou George	University of Thessaly
15	Eftychiadou Ourania	University of Thessaly
16	Eliou Nikolaos	University of Thessaly
17	Evangelinos Konstantinos	University of the Aegean
18	Fotiadis Stefanos	University of the Aegean
19	Galanis Athanasios	International Hellenic University
20	Galatsidas Spyros	Democritus University of Thrace
21	Georgantzis Nikos	Burgundy School of Business
22	Giannopoulos Giorgos	Democritus University of Thrace
23	Gkampoura Eleni-Christina	University of Thessaly
24	Gkargkavouzi Anastasia	Greek Ministry of Education and Religious Affairs
25	Gkouna Ourania	International Hellenic University
26	Grigoriadou Ioanna	International Hellenic University
27	Halkos Emmanuil G.	University of Thessaly
28	Halkos George E.	University of Thessaly
29	Hatjina Fani	Hellinikos Georgikos Organismos DIMITRA
30	Jones Nikoleta	University of Warwick, Institute for Global Sustainable Development
31	Kalessopoulos Chrysovalantis	University of Thessaly
32	Karatzoglou Benjamin	University of Macedonia, Hellenic Open University, International Hellenic University
33	Kasmeris Vasileios	International Hellenic University, Conservatoire of the Municipality of Kalamaria
34	Katsonis Nikolaos	Public Experimental I.E.K. Patras
35	Koliouska Christiana	Aristotle University of Thessaloniki
36	Kontos Dimitrios	Harokopio University, University of Thessaly
37	Kostakis Ioannis	Harokopio University

38	Kougias Konstantinos	Harokopio University
39	Kounetas Kostas	University of Patras
40	Kyriazis Nickolaos	University of Thessaly
41	Kyriazis Nikolaos A.	University of Thessaly
42	Latinopoulos Dionysis	Aristotle University of Thessaloniki
43	Lemonakis Panagiotis	University of Thessaly
44	Malesios Chrisovalantis	Agricultural University of Athens
45	Malindretos Georgios	Harokopio University
46	Marnasidis Simeon	Democritus University of Thrace
47	Matsiori Steriani	University of Thessaly
48	Meletiadis Georgios	University of Thessaly
49	Mitoula Roido	Harokopio University
50	Moutsinas Georgios A.	University of Thessaly
51	Nikolaou Ioannis	Democritus University of Thrace
52	Panagiotopoulou Altani	Athens University of Economics & Business
53	Papadopoulos Dimitrios	Politecnico di Milano
54	Papageorgiou George J.	University of Thessaly
55	Papageorgiou John G.	University of Thessaly
56	Papaspyropoulos Konstantinos G.	Aristotle University of Thessaloniki
57	Papavasileiou Angelos	Harokopio University
58	Paraskevopoulos Stefanos	University of Thessaly
59	Paschalidou Anastasia	Democritus University of Thrace
60	Patetsou Zoi	University of Thessaly
61	Patitsas Konstantinos D.	University of Thessaly
62	Prampromis Dimitrios S.	University of Thessaly
63	Profillidis Vassilios	Democritus University of Thrace
64	Raymand Farhang	Politecnico di Milano
65	Saiti Anna	University of West Attica
66	Sakellariou Stavros	University of Thessaly
67	Sardianou Eleni	Harokopio University
68	Skanavis Constantina	University of West Attica
69	Skouloudis Antonis	University of the Aegean
70	Stathi Eleni	Aristotle University of Thessaloniki
71	Stauropoulou Athanasia	Harokopio University
72	Stergiou Andreas	University of Thessaly
73	Tahiraj Joniada	University of the Aegean
74	Tsagarakis Konstantinos	Technical University of Crete
75	Tsekouropoulos Georgios	International Hellenic University
76	Tsekouropoulou Vasiliki	Aristotle University of Thessaloniki, Conservatoire of the Municipality of Kalamaria
77	Tsiantikoudis Stavros	Democritus University of Thrace
78	Tsiantoula Dimitra	Democritus University of Thrace
79	Tsiaras Evangelos	University of Patras
80	Tsompanaki Eleni	University of Thessaly, Model Dance School of the Municipality of Kalamaria
81	Verikouki Efstathia	Vocational School (EPAL) of Edessa

82	Vlachoudi Eleni	Primary Education of Western Thessaloniki
83	Zafeiriou Eleni	Democritus University of Thrace