VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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THE EVALUATION OF THE IMPACT OF ECONOMIC GROWTH ON GREENHOUSE GAS EMISSIONS

DOCTORAL DISSERTATION

SOCIAL SCIENCES,
ECONOMICS (04S)

VGTU LEIDYKLA

Vilnius TECHNIKA 2014

Doctoral dissertation was prepared at Vilnius Gediminas Technical University in 2009–2014.

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VGTU leidyklos TECHNIKA 2259-M mokslo literatūros knyga
http://leidykla.vgtu.lt

ISBN 978-609-457-700-0

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EKONOMIKOS AUGIMO ĮTAKOS ŠILTNAMIO EFEKTĄ SUKELIANČIŲ DUJŲ EMISIJAI VERTINIMAS

DAKTARO DISERTACIJA

SOCIALINIAI MOKSLAI,
EKONOMIKA (04S)

Vilnius LEIDYKLA TECHNIKA 2014

Disertacija rengta 2009–2014 metais Vilniaus Gedimino technikos universitete.

Mokslinis vadovas

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Acknowledgment

I am very grateful to Prof Dr Manuela Tvaronavičienė, the supervisor of this work, encouraging me to analyse the problems presented in the work.

I also thank the researchers of Vilnius University from the Faculty Mathematics and Information Technology for professional advice – Assoc Prof Dr Marijus Radavičius for consultations in econometrics and Assoc Prof Dr Pranas Vaitkus for consultations in statistical methods.

I highly appreciate generous help and scientific consultation of Dr Jolita Krumplytė during the studies.

My thanks are also due to my family, especially my husband, for understanding and moral support during the long-time of thesis writing.

This thesis is dedicated to the memory of my grandfathers, Assoc Prof Dr Alfonsas Bacys and Jonas Kilda, who in me the respect for science and love for nature.

Abstract

The dissertation is devoted to the pressing issue of preserving the environment in the course of economic development of countries. The problem of greenhouse gas emissions (further – GHG) associated with human activities is highlighted as one of the main environmental issues in today's world, which requires an immediate reaction and behavioural changes. The European Union is the leading region in tackling problem, and the reduction of GHG by 20 percent is explicitly introduced in European strategy 2020. In this context, there is a scientific debate how economic growth and the related processes and phenomena affect the environmental quality indicators. At the scientific level, there is a lack of different tools, allowing for evaluating the harmful effect of economic growth on environmental quality indicators, as well as for assessing the socio – economic and environmental policies. In the academic world, the centre of this discussion was so called the environmental Kuznets curve (further – EKC), representing the relationship between various environmental indicators and economic growth as the inverted-U trajectory. The technique and the model proposed by the author can be the instrument for assessing the impact of the economic growth and related factors, helping to reduce the height of the EKC, on GHG emissions and modelling various scenarios.

The dissertation consists of an introduction, three chapters, conclusions and annexes.

In Chapter 1, the state of the present investigation of the environmental Kuznets curve is considered, a critical overview of the empirical research is provided and the classification of relevant factors is presented.

In Chapter 2, the sequence of the evaluation of the impact of economic growth on GHG, including the reduced form model and the model, capturing some specific additional factors, such as the economic structure, research and development expenditure, environmental taxes, energy taxes and sustainable business, is described.

In Chapter 3, the empirical analysis of the evaluation of the impact of economic growth on GHG based on the proposed model, which was made for the selected European countries in the period of 1995–2011, is presented as well as three scenarios, showing the impact of economic growth and other special factors on the level of GHG, are modelled.

Reziumė

Disertacija skirta aktualiai problemai – vertinti žmogaus ūkinės veiklos daromą žalą gamtai ekonomikos augimo sąlygomis. Šiltnamio efektą sukeliančių dujų (toliau – ŠESD) kiekio didėjimas, sukeltas žmonių veiklos, lemia klimato kaitą. Tai yra viena iš pagrindinių šių dienų aplinkosaugos problemų, kuri reikalauja adekvataus reagavimo ir žmonijos elgesio pokyčių. Europos Sąjunga yra vienas iš pirmaujančių regionų, sprendžiant šią problemą. ŠESD kiekio sumažinimas 20 % iki 2020 m., lyginant su 1990 m., yra apibrėžtas Europos strategijoje „Europa 2020". Šiame kontekste vyksta mokslinės diskusijos, siekiant įvertinti ir pagrįsti, kaip ekonomikos augimas bei jį sąlygojantys įvairūs procesai ir reiškiniai lemia aplinkos kokybės rodiklių tendencijas. Moksliniu lygmeniu nepakanka instrumentų, kurie sudarytų galimybes analizuoti ekonomikos augimo įtaką aplinkos kokybės rodiklių neigiamoms tendencijoms, įvertinant socialines–ekonomines bei aplinkosaugos politikas. Šių mokslinių diskusijų centre yra aplinkos Kuznetso kreivės (toliau – AKK) tyrimai, apimantys ekonomikos augimo įtakos įvairiems aplinkos kokybės rodikliams vertinimus, kurių rezultatai vaizduojami kaip atvirkštinė „U" raidės formos kreivė. Autorės pasiūlyta metodika ir empiriškai patikrintas modelis tinka modeliuoti ekonomikos augimo bei tam tikrų veiksnių (lemiančių AKK aukštį) poveikį ŠESD kiekiui bei modeliuoti galimus scenarijus.

Disertaciją sudaro įvadas, trys skyriai, išvados ir priedai.

Pirmajame skyriuje atlikta ekonomikos augimo įtakos aplinkos kokybės rodikliams mokslinės literatūros analizė, apimanti AKK tyrimų raidą, kritiškai įvertinti empiriniai tyrimai, susistemintas esamas metodinis potencialas bei pateikta AKK veikiančių veiksnių klasifikacija.

Antrajame skyriuje pateiktas autorės siūlomas ekonomikos augimo įtakos ŠESD kiekiui tyrimo modelis, kurio esmė – klasikinio AKK modelio išplėtimas papildomais veiksniais (ekonomikos sektorių struktūra, aplinkosaugos mokesčiai, energijos mokesčiai, mokslinių tyrimų ir eksperimentinės plėtros išlaidos, darnaus verslo rodiklis). Modelis sudaro galimybes integruoti ir adekvačiai įvertinti įvairių veiksnių įtaką nagrinėjamam reiškiniui specifiškai susiklosčiusiomis tam tikros valstybės ar regiono ekonomikos ir aplinkosaugos raidos sąlygomis.

Trečiajame skyriuje pagal autorės pasiūlytą modelį atliktas ekonomikos augimo įtakos ŠESD kiekiui empirinis tyrimas, naudojant 1995–2011 m. Europos valstybių rodiklius bei pateikti trys autorės sumodeliuoti scenarijai, kurie parodo ekonomikos augimo ir tam tikrų veiksnių poveikį ŠESD kiekiui.

Abbreviations

BOD – biochemical oxygen demand;
CEE – Central and Eastern Europe;
CH_4 – methane;
CO_2 – carbon dioxide;
EGLS – Estimated General Least Squares;
EKC – Environmental Kuznets Curve;
ESG – Environment, Social and Corporate Governance;
EU – European Union;
EUROSTAT – Bureau of European Statistics;
GDP – Gross Domestic Product;
GHG – Greenhouse Gas Emissions;
GLS – General Least Squares;
HFCs – hydrofluorocarbons;
ISO – International Organization for Standardization;
LR – Republic of Lithuania;
NAFTA – North American Free Trade Agreement;
NO_2 – nitrous oxide;
OECD – Organisation for Economic Co-operation and Development;
OMX GES – Nasdaq OMX Global Indexes;
PFCs – perfluorocarbons;
PPP – Purchasing Power Parity;
R&D – Research and Development;
SD – Sustainable Development;
SF6 – sulphur hexafluoride;
SO_2 – sulfur dioxide;
UK – United Kingdom;
UN – United Nations;
UNCSD – United Nations Conference on Sustainable Development.

Contents

Introduction

The Investigated Problem

For a long while, humans have believed that the planet is capable to restore the damage made by their activities. The new inventions at the end of 18^{th} century led to the industrial revolution and over the period of about 150 years the natural processes of the planet had been broken. Since the 1970s, when the Club of Rome put forward the theory of „limits to growth“, the environmental quality has been considered as another one prerequisite for economic growth (Meadows *et. al* 1972). The problems associated with the harm of the economic growth (usually, measured by gross domestic product, further GDP) to the environment and possibilities to sustain economic growth without running into the potentially irreversible process of environmental destruction have been discussed by environmental economics. The so called environmental Kuznets curve (further – EKC) appeared to be in the centre of this discussion after the publication of seminal works of G. Grossman and A. Krueger (Grossman, Krueger 1991; 1995). The relationship between various indicators of environmental degradation and income per capita was analysed and it was found that in many cases this relationship could have the inverted-U form. This indicates that, at the early stages of economic growth, the environmental degradation and pollution are increasing, but beyond some level of income, the trend reverses so that the economic growth leads to the environmental improvement. The problem of greenhouse gas emissions (further – GHG) caused by human activities is highlighted as one of the main environmental issues in today's world, which requires an immediate reaction and behavioural changes. According to professor Nicholas Stern (2009), emissions have been strongly correlated with GDP per head across time and countries and without action to combat climate change, atmospheric concentrations of greenhouse gases will continue to rise, future emissions growth will come from today's developing countries, because of rapid population and GDP growth than developed countries. It is impossible for an individual country to 'grow up' the climate change. At the scientific level, there is a lack of different tools, allowing for evaluating the harmful effect of economic growth on environmental quality indicators, as well as for assessing the socio–economic and environmental policies.

Importance of the Thesis

Environmental degradation and, particularly, the climate change have been analysed by many scientists and politicians from various perspectives. At the political level, the United Nations Framework Convention on Climate Change was signed in 1992, in order to stabilize GHG emissions at the level, which could help to prevent dangerous anthropogenic interference with the climate system. The Kyoto Protocol is the main document providing for the parties' commitments to reduce GHG emissions, but its ratification is acomplicated and time–consuming process. In the European Union, the issues of the climate change have been fixed in the 'Europe 2020', EU strategy for sustainable development and the National Strategy for Climate Change Management Policy. In 'Europe 2020' strategy, the targets is 20% reduction of greenhouse gas emissions since 1990 till 2020 and the vision of reduction by 80% until 2050. The European Union countries have reduced greenhouse gas emissions since 1990, but the target of 20 percent has still to be reached. The main problem of maintaining the stable economic growth rate and, at the same time, slowing down the level of GHG is highlighted in the National Strategy for Climate Change Management Policy (2012) and in the interinstitutional plan of activities aimed at implementing the goals and tasks of the National Strategies for Climate Change Management for the period of 2013–2020 (2013).

The Object of Research

The impact of economic growth and other factors on GHG emissions for EU countries in the period of 1995-2011, based on the investigation of environmental Kuznets curves.

The Aim of the Thesis

To suggest a technique for evaluating the impact of economic growth on the indicators of environmental degradation and, based on the created technique, to perform the model for analysing the considered interrelationship.

The Tasks of the Thesis

The following tasks have been set to achieve the goal of the dissertation:

1. To analyse the literature on the impact of economic growth on the indicators of environmental degradation, to describe the state of the present investigation of the environmental Kuznets curve, to provide a critical overview of the empirical research, to summarize the available methodical tools and to give a classification of relevant factors.
2. To analyse the specific of the indicator of GHG in the particular object, to identify the suitable factors and to incorporate them into the model.
3. Based on the analysis of econometric issues, to create the technique with the aim of evaluating the impact of economic growth on the indicators of environmental degradation.
4. Based on the created technique, to perform the empirical validation of economic growth on GHG emissions in EU countries.
5. Based on the specified model, to analyse various scenarios of the impact of economic growth on GHG emissions during the empirical validation.

Research Methodology

To evaluate the research object, the methods of induction, deduction and empirical research have been used as cognitive techniques. The analysis of the scientific literature was based on systematizing, comparison and generalization of the scientific statements and results of empirical research. For the empirical testing of the hypothesis, such methods as data normalisation, multiple regression and a fixed effect panel model have been used. The triangulation principle was implemented for the empirical validation of the hypothesis for different periods and specific countries or their groups. The research results have been statistically treated using the Eviews software and presented in charts using MS Excel.

Scientific Novelty of Dissertation

The following new results in the field of economics have been obtained in the present investigation:

1. Theoretical principles of evaluating the influence of the economic growth on the environmental degradation have been extended by systemizing the factors influencing AKK and empirically tested proxy variables.
2. The three – stage technique, covering classification of the types of countries based on the classical EKC model, identification and evaluation of new factors and modeling scenarios has been constrained.
3. A model integrating the main factors influencing the emissions of the GHG (sectorial structure, environmental taxes, energy taxes, research and experimental development expenditure and sustainable business), which is suitable for modelling the trends of EKC development, has been created and empirically tested.

Practical Significance of the Obtained Results

The technique, capturing three steps analyses and the inclusion additional factors shall be useful enabling to examine the impact of economic growth on the environmental degradation. In the dissertation the presented evaluation model has been verified by empirical research the results of which may be useful for scientists and practicians (e.g. for Ministries of the Environment and Economy), analysing the trends of the economic development of the countries, and dealing with the problems of the relationship between the environmental indicators and economic growth.

The Defended Statements

1. Based on the proposed technique, the created model integrating the main factors influencing the emissions of the GHG (sectorial structure, environmental taxes, energy taxes, research and experimental development expenditure and sustainable business), which is suitable tool for evaluating the trends of the impact of economic growth on the indicators of environmental degradation in the course of the sustainable development of the country.

2. The analyzed countries in the region may be subdivided into groups according to the reduced EKC model in order to model scenarios, making the assumption, that countries in the region have the homogenous development tendencies.
3. The proposed model is the most suitable for the states, being at the early stages of development (the beginning part of EKC) with the aim to model further tendencies.

Approval of the Results

Seven articles focusing on the subject of the dissertation have been published: one was published in the journal quoted by ISI Web of Science, others – in the journals of EBSCO, Scopus and other editions and conference proceedings. Two presentations on the subject have been made at the scientific conferences. Fours presentations on the subject have been made in scientific seminars.

Dissertation Structure

The scientific work consists of the introduction, three chapters, general conclusions, list of literature (211), list of the author‘s publications and annexes. The total volume of the dissertation is 118 pages (without annexes), including 10 pictures, 17 tables and 8 annexes.

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In Chapter 3, the empirical analysis of the evaluation of the impact of economic growth on GHG based on the proposed model, which was made for the selected European countries in the period of 1995–2011, is presented as well as three scenarios, showing the impact of economic growth and other special factors on the level of GHG are modelled.

1

The Analysis of Environmental Kuznets Curve

Since the 1970s, when the Club of Rome put forth the theory of “The Limits to Growth“, the environmental quality has been considered a new prerequisite for economic growth. The idea has passed from academic and environmental activists to political handling. At the highest political level, the environmental problems have been viewed as very important for the development of the country since 1972, when Stockholm Conference on the Human Environment was held and sustainable development as the leading paradigm has been resurfaced. In the academic world, the centre of this discussion was so called the environmental Kuznets curve, representing the relationship between various indicators of environmental degradation and economic growth.

The aim of this chapter is to describe the evolution of the EKC curve, starting from its roots till nowadays, to summarise the results of empirical studies and systemise the possible theoretical factors influencing the relationship between the environmental indicators and economic growth.

The chapter has the following structure. In Section 1, the most influential theories of the environmental economics are described to highlight the environmental aspect. In Section 2. a thorough analysis of the EKC evolution since its root till our days is presented. In Section 3, the systematic analysis of theoretical factors influencing the relationship between the environmental indicators and economic growth is given.

The data presented in the chapter can be found in the published articles of the author (Lapinskienė *et al.* 2014; 2013; Lapinskienė, Radavičius 2014).

1.1. The Interrelation of Economic Growth and the Indicators of Environmental Degradation

In the scientific world, the question if the economic growth harms the environment has been widely discussed by environmental economists for a long time. The question of how a continuous economic growth affects various environmental indicators is very important and has been analysed by many scientists. According to Panayotou (1993), the environmental problems based on their relationship to economic growth could be generally described as follows:

1. The increase of economic growth should be stopped and economies should move to the steady state economy (Meadows *et al.* 1972; 2004).
2. The increase in economic growth leads to environmental improvement and, therefore, countries may become richer (Beckerman 1998).
3. The relationship between the economic growth and the environment changes demonstrates the inverted−U trajectory (Grossman, Kreuger 1993; Selden, Song 1994; Panayotou 1993).

The first one covers the ideas of environmentalist like Meadows and other researchers, who supported the limiting of the countries' economic growth. The second approach, having the least number of followers, suggested that no strict regulation is needed as it could be harmful to economic growth, which by itself would improve the environment (Beckerman 1998; Bartlett 1994). The third approach named EKC, which lately has become very popular among many scientists, raises many other questions about the turning points, the level of the environmental damage and possibilities to avoid them, as well as the role of policies and regulations and the possibilities for the developing countries, or the countries in transition, to learn from the developed countries how to avoid the environmental damage and to find the political tunnel.

In 1798, Thomas Malthus wrote a book "An Essay on the Principle of Population". In this book, the author assumed that food supply grew only arithmetically, while a healthy population grew geometrically (Malthus 1798). It was called the Malthusian population trap where long−run human progress would be very dim. The author did not assess the technological progress, and the land was defined as an irreplaceable source of natural capital. A great number of ecological economists follow the idea of T. Malthus and refer to his famous book in their works.

The theoretical considerations of the relationship between the environment and economic growth starts, in many cases, with presenting the famous book

"The Limits to Growth" (Meadows *et al.* 1972) inspired by the informal organization The Club of Rome. It was noticed that the rates of such variables as population growth, usage of resources, level of pollution and material consumption grew according to the trajectory of the exponential function. They warned that the patterns of production had to be changed from quantity to quality and noticed that it was impossible to satisfy the infinite needs of every human, therefore, the necessity of choice would be inevitable. Various scenarios were built in examining the growth of the selected variables, according to which the limits of the planet would have stopped the growth in the 21th century. The authors suggested gathering the data on the development of the world in order to track and manage the processes of growth. They thought that such growth could not continue more than one hundred years and suggested the work to step into the global equilibrium and to put more efforts to preserve the environment. Since the publishing of this book, the environmental quality has been considered to be a new prerequisite for economic growth. The world has recognized new challenges and its responsibilities for changing the climate and depleting natural resources. In 1968, another book "The Population Bomb" warned about the overpopulated Earth. As the man changed the axe into the machine, the environment lost the battle, because a man is so brutal with the infinity of his needs. The author called people to recognize that the growing population would change the living standards and the natural beauty of the environment. The solution suggested writing letters to politicians that they could see that people want to control this problem. It was thought necessary to plan for a stable population of optimum size. Family planning alone did not lead to population control. The attitude of population had to be changed. Otherwise, it was believed that the environmental deterioration would pose a colossal threat to man's survival (Ehrlich 1968).

In 1992, the new book of the authors "The Limits to Grow" called "Beyond the Limits" was published. Using the updated results, the authors emphasized that the natural processes of the planet were broken, therefore it was very important to recognize that and make changes to alter the current path. Later, the scientists continued to study the possible scenarios for the world, comparing the results presented in the previous studies. Donella Meadows, Jørgen Randers, and Dennis Meadows updated their studies and published the book "The Limits to Growth: The 30-Year Update" (Meadows *et al.* 2004). Starting this new book, the authors acknowledged many positive things that were done in order to preserve the environment during the past years. However, the rate of population, production and pollution were still rising, despite the emergence of new technologies and innovations. Modelling the World3-3 scenarios, the scientists included new components of rates. One of their conclusions was that it was very important to manage an orderly reduction of their activities back down below the limits of the earth's resources.

In 2012, Randers, one of the authors of “The Limits to Growth", published the book “2052 Global Forecast and Report to the Club of Rome”, where he forecast the future in order to answer the so frequent question given to him during the forty years. This question was as follows: what would happen in another forty years? He noticed that the real challenge was to estimate how much (or how little) of what needs to be done would actually be done. He believed that the transition to sustainability would be only half complete by 2052, because the human response to the environmental degradation is too slow. In the book, the most critical factor was highlighted as greenhouse gas emissions from human activities. The transition to sustainability will require a fundamental change to a number of the systems that govern the current world development: capitalism, economic growth, democracy, intergenerational equity and our relationship with the earth’s climate. The author chose to forecast or trace the big lines of what he sees to be the probable global evolution toward 2052. Technically, the trends and tendencies that are rooted in stable causal feedback structures in the world system are described. As the author pointed out, his forecast did not eliminate free will, but rather was based on the belief that human decision making was influenced by the conditions under which the decision was being made. The book includes about thirty five glimpses of different experts in areas, which were chosen as important parts for the painting sketch. Not going further into detail in describing this book, we present below the main messages which are related to climate change and executive research in this work.

The main messages of 2052 are as follows:

- The population will peak at 8.1 billion people just after 2040 and then decline, because fertility will fall dramatically.
- The global GDP will grow more slowly than expected because of the lower population growth and declining growth rates in productivity.
- The growth rate in global consumption will slow because a greater share of GDP will have to be allocated to investment in order to solve the problems created by resource depletion, pollution, climate change, biodiversity loss, and inequity.
- As a consequence of increased social investment in the decades ahead, resource and climate problems will not become catastrophic before 2052.
- The short–term focus of capitalism and democracy will ensure that the wise decisions needed for long–term well–being will not be made in time.

The author, building his forecast on the system dynamic models, embodied a lot of academic theory drawn from economics, political science, sociology, engineering, biology, agriculture and environmental science. The forecasting was built on two questions: 'what will happen to consumption over the next forty years? Under what conditions – in what social and natural environment – will that future consumption take place?' (Randers 2012).

In the interview, the author pointed out, that to stop climate change, it is necessary to reduce global emission by half, which would cost 2% of GDP. He kindly pleased everybody not to think only about his comfort, but to contribute to minimizing the harmful impact to climate.

The latest studies of the environmental degradation and growth are related to the hypothetical Kuznets curve approach. The environmental Kuznets curve is a hypothetical relationship between various indicators of environmental degradation and income level, referring to the shape of the inverted−U. The graphical chart of the EKC hypotheses is given below.

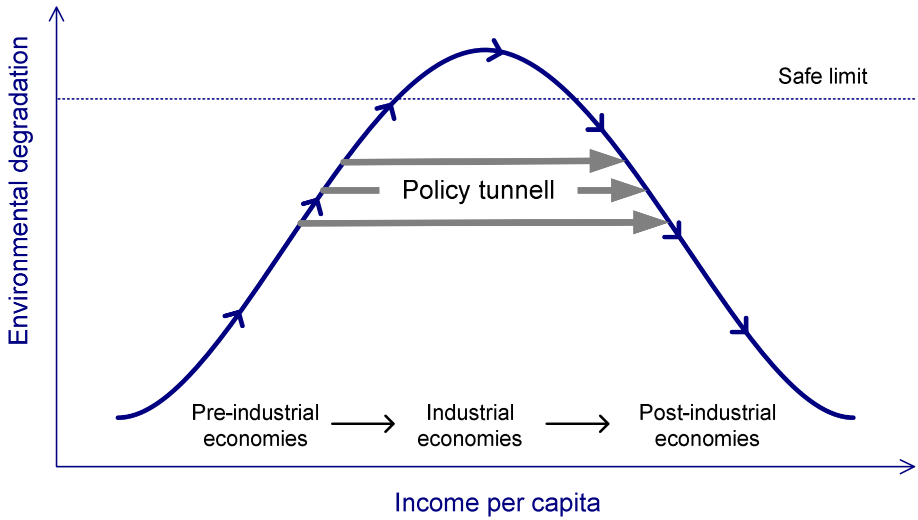


Fig. 1. The Environmental−growth relationship, the EKC approach
Source: R. Čiegis „Gamtos išteklių ir aplinkos ekonomika“ p.147

As can be seen in the figure, at the early stages of economic growth (which can be called pre-industrial economies), the degradation and pollution are increasing, but beyond some level of income per capita (reaching the turning point at industrial economies), which varies for different countries, the trend reverses so that, at high income levels (the stage of post-industrial economies), the economic growth leads to the environmental improvement. This implies that the environmental impact indicator is the inverted U-shape function of income per capita. In their studies, Dasgupta and Maler (1994) called this empirical relationship between national income per head and concentration levels of industrial pollutants the environmental Kuznets curve.

According to Čiegis (2002), the environmental Kuznets curve should not be used as a proof or a critical argument in grounding the statement that economic growth is sufficient to achieve the environmental improvement and as the main argument in building national sustainable development strategies. It should be viewed as the hypothesis on the interrelation between economic growth and the environmental quality. Hence, this instrument might be useful for the analysis of additional instruments in order to reduce the height of the EKC based on the learning from the experience of other countries and by adopting policies that permitted to "tunnel" through the curve and provide scientific information to sustainable policy design.

According to Goodstein (2010), three positions are often staked out in economic discussions regarding environment protection: an efficiency position, safety standard supporters, sustainability. Since the 1970s, when the Club of Rome put forth the theory of "The Limits to Growth", the environmental quality has been considered as a new prerequisite for economic growth to sustainable development. The most resounding alarm was produced by the Club of Rome headed by the environmental economist Donella Meadows, the principal author of the book 'The Limits to Growth' (1972). Since then, the world has recognized new challenges and responsibilities for changing the climate and diminishing natural resources. Rapid degradation of environmental resources and increasing pollution led to the recognition of some environmental problems as the priority tasks. The idea has passed from academic and environmental activists to political handling. At the highest political level, environmental problems have been viewed as very important for the development of the country since 1972, when Stockholm Conference on the Human Environment was held. In 1972, the United Nations Conference on the Human Environment in Stockholm 'considered the need for a common outlook and for common principles to inspire and guide the peoples of the world in the preservation and enhancement of the human environment' (UN 1972). The concept of sustainable development as the major developing strategy, equally embracing economic, social and environmental pillars, was introduced. The term 'sustainability' was derived from forestry where this term was related to natural development of forests and was called 'Sustained Yield Forestry' (Mitchel 2010; Rogers 2009). Further in 1987, the World Commission on the Environment and Development issued a report ‘Our Common Future’. According to the full definition of the Brundtland Commission, ‘sustainable development is the development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.’ It contains two key concepts: the concept of 'needs', in particular, the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs (Brundtland 1987). This term, reflecting holistic thinking, is now recognized to be the key expression. The other two core events contributing to the evolution of sustainable development were the 1992 UN Conference of Environment and Development and at the 2002 the World Summit on Sustainable Development (UN 1992; UN 2002).

In 2012, The United Nations Conference on Sustainable Development was organized in Brazil. This conference highlighted two themes: green economy in the context of sustainable development and poverty eradication, and the institutional framework for sustainable development. In this conference, green economy in the context of sustainable development and poverty eradication was highlighted as the tool enhancing human being ability to manage natural resources sustainably and with lower negative environmental impacts to increase the efficiency of resources and the reduce waste (UNCSD 2012). The terminology of green economy was not new. It was derived from ecological modernization.

The EU sustainable development strategy was launched by the European Council in Gothenburg in 2001, renewed in 2006 and in 2009. During the period of forty years much effort was made to analyse this paradigm (Stankevičienė *et al.* 2014; Rutkauskas 2012; Tvaronavičienė, Grybaitė 2011; Ginevičius, Podvezko 2007). In Lithuania, the Lithuanian National Strategy for Sustainable Development was approved by the Government of the Republic of Lithuania in 2003 and renewed in 2009.

The concept of sustainable development has been used for more than 40 years. There were many critics alleging that to develop and sustain at the same time is an oxymoron, therefore the need was acknowledged to further mainstream sustainable development as the main strategy at all levels, integrating economic, social and environmental aspects.

Environmentalists and other researchers aiming at preservation of the natural environment feel huge hopelessness as the behavioural patterns of human beings as partly biological species and partly social animals are so destructive to natural environment. Three concepts have been developed with the aim of preservation of the environment. The first concept is associated with the limiting of economic growth (concept which is almost impossible to apply in the current society), the second one is the idea of outgrowing the environmental problems with a higher growth and the third concept is related to the EKC theory highlighting the managing environment issues in the course of the economic growth. Despite the growing efforts, the environmental problems are still very acute and the natural environment are destroyed beyond repair in many places, supporting the critics that sustain and develop is oxymoron.

Hence, the growing population and consumption are the main causes of the environmental degradation. The issues of growing population is not the research object of this dissertation. It is decided to GDP and GHG per capita in order to eliminate the impact of the growth of population on GHG and make comparable data of countries of different sizes.

1.2. Economic Growth and the Environmental Degradation: the Analyses of the Evolution of Empirical Research

1.2.1. The Evaluation of Classical Environmental Kuznets Curve Studies (1991–1995)

The relationship between the economic growth and environmental quality presented by the inverted–U has been widely studied since 1990s. Dasgupta and Maler were the scientists who named the relationship between the income per capita and industrial pollution the environmental Kuznets curve. Many journals, such as Ecological Economics, Energy Policy, Energy Economics, Economic Modelling, and many others, published the articles considering the issues of the relationship between the environment and economic growth. Researchers used different the indicators of environmental degradation – air pollutants, e.g. CO_2 (later GHG), SO_2, and water indicators, waste and other specific environmental indicators from the environment–related databases, such as Global Environmental Monitoring System (GEMS), OECD, the Oak Ridge National laboratory, Eurostat and national statistics. In the presented figure, the role of the authors who investigated the EKC is shown. The main researchers who contributed to this investigation have been grouped according to the dates of their research (see Figure 2).

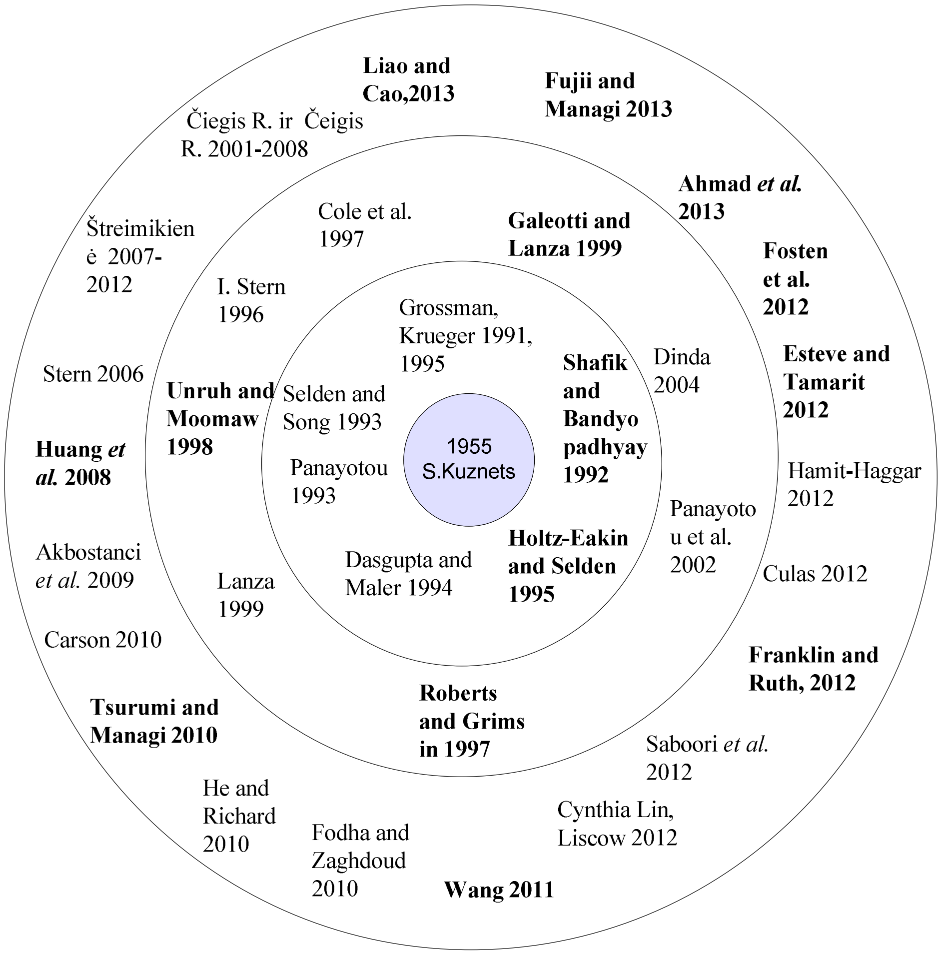


Fig. 2. The main researches works dealing with the issue of EKC
*in bold, researchers performing the analyses with CO_2 or GHG.
Source: by author

Originally, the environmental Kuznets curve was derived from the Kuznets curve. In 1955, Kuznets became interested in the character and causes of the changes in inequality of personal distribution of income in the course of the economic growth of a country. He tried to define the factors reflected in the long–term trends in personal distribution changes in income. The analysis of the available data in the United States, UK and Germany highlighted some trends of decreasing income distribution inequality in the developed countries. The researcher highlighted two potential causes of the increasing income inequality, which were the concentration of savings in the upper−income brackets and an industrial structure (the shift from agriculture to industrialization and urbanization) in the developed countries. The impact of the concentration of savings is limited by political (e.g. regulations) and demographical factors, the very nature of dynamic economy (freedom of individual opportunities leading to technological changes and the rapid growth of new industries) and a part of the service sector (specifically professional and entrepreneurial earnings). The impact of the second cause (an industrial structure) was detailed in the analysis of various scenarios of possible income trends' defining sectors, such as agriculture and the other sectors. The scenario analysis indicated a possible path of the increase of income inequality at the early stages of the process of changing the industrial structure. However, it also demonstrated its decrease at the late stages due to a higher overall income. The analysis was extended by the comparison of the developed and developing countries (the statistical data on the developing areas was taken for India, Ceylon and Puerto Rico). The scientists assumed that the income structure was somewhat more unequal in the developing countries than in the more advanced ones, despite some limitations of the comparison data. In general, Kuznets hypothesized that, at the early stages of development, when the income per capita was growing, income inequality was supposed to increase, but above some income level, the inequality would decline, thereby demonstrating the inverse−U−shaped relationship between the level of income inequality and income growth. This relationship became known as the Kuznets curve. The author also recommended to study the economic growth by more deeply analysing the population growth patterns, the nature of this growth and forces causing technological changes, as well as the development of political institutions and, generally, the behavioural patterns of human beings as partly biological species and partly social animals (Kuznets 1955).

Environmental economists have built on this concept by hypothesizing the same type of the relationship between the level of the environmental degradation and income growth. Many researchers have agreed that Grossman and Krueger were the scientists who boosted the research. In the article published in 1991 by Grossman and Krueger, the authors used the comparable measures of three air pollutants (sulphur dioxide, dark matter and suspended particles) in a cross−section of urban areas located in 42 countries, to study the relationship between the air quality and economic growth in the context of liberalization of trade between the United States and Mexico. The study was inspired by the discussion on the potential North American Free Trade Agreement (NAFTA). With regard to this agreement, environmentalists expressed a doubt that free trade and direct investment flows between the United States and Mexico might aggravate pollution problems in Mexico and in the border region. It was stated that the country's weak regulatory infrastructure would not be able to control the industrialization processes that derived from the liberalization of trade and investment. According to the authors, a reduction in trade barriers generally affects the environment by expanding the scale of economic activity, as well as by altering the composition of economic activity and bringing about a change in the techniques of production. These explanations have become the classical theory of the relationship between growth and environmental indicators, which is known as the EKC. At that time, little was known about the empirical relationship between national income and concentrations of various pollutants. The Global Monitoring System provided the data on several pollutants in a cross−section of the urban areas, using standardized methods of measuring the concentrations of sulphur dioxide and suspended particulate matter through the world. These environmental data with the explanations of possible discrepancies was taken as a dependable variable for examining how air quality varied with economic growth. Mexico did not participate in this reliable measuring of air pollution, therefore it was not possible to know the particular relationship between toxic waste and industry outputs in the country. The predictions for Mexico had to be inferred from other countries because they passed similar stages of development. The areas included in the project were classified centre cities, suburban areas, commercial, industrial, or residential centres. The authors also included the functions of per capita GDP in the country, where the city was located, as well as characteristics of the city, and the time trend. The cubic equations were taken as mathematical expressions fitting the considered data fairly well. Dummy variables captured the location, the purpose of the land use, the method of measurement, as well as the fact whether the city was located along a coastline or was ruled by a Communist government. They have found, through the examination of air quality measures in a cross−section of countries, where economic growth tends to be closely connected to pollution problems, once a country's per capita income reaches about a per capita threshold of US$5,000. This was defined as a critical juncture in the development process, where further growth should generate the increased political pressures for environmental protection and, perhaps, a change in private consumption behaviour. It was assumed that trade liberalization might well increase Mexican specialization in sectors that cause less than average amounts of environmental damage.

This concept was popularized through the 1992 World Bank Development Report. In this report, the protection of the environment was defined as an essential part of the development, and it was emphasized that without adequate environmental protection the development would be undermined. On the other hand, without the development, the resources required for investments would be inadequate, and the environmental protection would fail. Hence, a positive impact of growth on the environment was determined. Authors used some additional environmental indicators and more countries to find that the environmental quality was monotonically improving (due to the reduction of pollutants with the exception of the amount of the dissolved oxygen in rivers and CO_2), when the level of income was rising. It was found that CO_2 emissions per capita increased monotonically during the income growth with unidentified income turning point (Shafik, Bandyopadhyay 1992).

In 1994, Selden and Song continued to test the relationship between the environmental quality and the development, following the above – mentioned studies of Shafik and Bandyopadhyay (1992), as well as Grossman and Krueger (1991; 1995). The authors made the assumption that industrialization and agricultural modernization might lead to increased pollution, while other factors might cause its decrease. Selden and Song (1994) emphasized the role of the following factors: positive income elasticity for environmental quality, the changes in the patterns of production and consumption, as well as the increasing levels of education and environmental awareness and the development of more open political systems. The researches limited their study to air quality indicators (e.g. sulphur dioxide, suspended particulates, oxides of nitrogen and carbon monoxide). They hypothesized that urban air quality would be reduced more than aggregate emissions at lower levels of per capita income. The reasons behind this hypothesis were the importance of the urban quality for public health: lower cost of urban quality improvement and reallocation of the dirty industries to other areas by rising land rents or using the political power. The authors were contributed to the environment and growth debate by making forecasts of global emissions under the different scenarios of income and population growth. They highlighted three interrelated factors which could be important for the future scenario of global pollution as follows: the distribution of global income, the pattern of income growth rates among various nations and the pattern of the population growth rates among the nations. The authors used the quadratic regression equation to integrate in one model the emissions per capita, real GDP per capita and an additional variable – the population density. In the frame of this model, a meaningful Kuznets relationship between the emissions and GDP was expressed via possible signs of regression coefficients. The researchers expressed concerns about the exclusion of other potential explanatory variables that could be grouped into endogenous and exogenous factors. Some examples of exogenous factors of growth include the composition of output, the level of education and the political structure, while climate and geography were presented as exogenous factors of emission. They offered the model of error components, which included the country and the year effect. The authors found a significant support to the inverted–U hypothesis with the turning point higher than US$8000. Using the estimation results, they predicted the future path of global emissions development by transforming a quadratic equation. The researchers made a forecast of global emissions under a number of scenarios for the conditions of income and population growth. The forecast indicated that global emissions would not return to their current levels before the next century, even under most optimistic scenarios. The authors were cautious about these results for several reasons: they had not forecast the technological changes and had not incorporated policy responses as well as shifts of polluting activities from the rich to the poor countries, etc. (Selden, Song 1994).

The actual issue of global warming induced the scientists Holtz–Eakin and Selden (1995) to carry out the research based on CO_2 and GDP. In 1995, the researchers debated the future path of greenhouse gas emissions and global economic development. This discussion is still important now. The authors concentrated their analysis on two emission functions: the first that is quadratic in levels and the second, which is quadratic in the natural logarithms. They determined that endogenous variables might be the composition of output, regulations and taxes, as well as patterns of urbanization. Some country–specific factors, including climate, geography, resources, land area, etc., were mentioned as exogenous variables of emissions. Emission data included emissions associated with aggregate fossil fuel consumption and cement manufacture. The panel data covered completely 108 countries for the years 1951 to 1986. The estimation results increased with per capita GDP, but, eventually, they decreased consistent with the inverted – U shape. The researchers used the estimated relationship to forecast the global emissions due to fossil fuel consumption and cement manufacturing over the period 1986–2100. For the future estimation, the forecast data of GDP per capita and population for each country were taken from the World Bank projections. The authors commented that such forecast could be more useful for the next several decades. The authors also forecast the annual emissions growth by about 1.8 percent annually (compared to 3.2 percent in 1955–1985). They found the diminishing marginal propensity to emit in overall sample, but since most of the world population is concentrated in the countries where income, population and emissions are increasing at the highest rates, these nations overweight the slowing growth of emissions in wealthier nations. Testing of various scenarios for the forecast resulted in the conclusion that neither different growth path, nor price and innovation changes within a historical range would help to limit overall accumulation of CO_2, and scientists argued that this process could be slowed only by taxes, which were large relative to historic fuel prices (Holtz–Eakin, Selden 1995).

Later, Grossman and Krueger (1995) continued to search for the answer to a difficult and complex question about the effect of economic growth on ecological problems. The scientists believed that their findings could be very useful for creating the appropriate development strategies for other countries. They made an assumption that the development gave rise to structural changes in production, and the societies should find ways to conserve scarce resources. They believed that the forces of innovation would be so strong that they could compensate for the harmful effects of economic growth on the environment. Otherwise, they believed that the damage to the environment would be directly linked to the scale of economic activities. In order to test this, they examined the reduced−form relationship between per capita income and various environmental indicators, such as urban air pollution, the state of the oxygen regime in river basins, the faecal contamination of river basins, and the contamination of river basins by heavy metals. In general, the research demonstrated that national income was an important determinant of local air and water pollution. The authors found that for the most indicators, the pollution increased at the initial stage, but, in the course of the economic growth, a subsequent phase of improvement was fixed. The authors suspected that these improvements were the results of the increased demand and supply for environmental protection at higher levels of national income. The authors concluded that the turning points in these relationships varied for different pollutants, while, in most cases, the turning point was less than 8000$ income per capita. The researchers highlighted that positive changes were impacted by structural transformation, when dirty technologies were changed and stringent environmental standards and laws were implemented. Another reason was associated with reallocation of dirty technologies to the countries with unrestricted environmental regulations. They made a hypotheses that such kind of trade is too small to account for the reduced pollution. They expected that the low−income countries would have an opportunity to analyse the path of the developed world and find their policy tunnel to better environmental protection in the course of their economic growth. (Grossman, Krueger 1995).

Based on empirical researches, the first studies highlighted the special turning points, when the positive changes were impacted by structural transformation, when dirty technologies were changed and more stringent environmental standards and laws were implemented. The summarised concluding remarks of the first influential studies lead to the notion that countries have to be very innovative in creating and implementing various mechanisms to preserve environment.

Moreover, the scientists (whose works are discussed above) can be referred to the classics of the EKC. The overview of the literature presented in this paragraph ends with the critical remarks of Stern *et al.* (1996) found in the article ‘Economic Growth and Environmental Degradation: The environmental Kuznets curve and Sustainable Development’. D. I. Stern is a prominent EKC researcher, who published many articles on the environment and economic growth. The EKC concept was criticised from two perspectives – the economic point of view and econometric methodology for empirical research. Reviewing the main investigations of the problem, the authors concluded that there were some problems associated with EKC estimation. According to the authors, the changes in trade relationship associated with the development were not included in the previous models. The neutral effect of trade in the models caused fundamental problems associated with the EKC hypothesis. The researchers noticed that the EKC was built on the economic assumption, where was no feedback, showing how the state of environment affects the economic growth. The decreased quality of the environment might lead to a lower quality of life, but not to the reduction of production possibilities. Hence, the economic growth could not be presented as the best solution for poor countries. On the other hand, the developing countries would make unsustainable growth. The authors noticed that estimation of a single equation did not refer to the different causal chains and could not be the main instrument to achieving the sustainable development policy, which, in reality, was characterised by many criteria. A structural model might be more suitable than a single regression. The countries importing raw materials might be exporting the environmental impacts to other countries. The authors concluded that historical experience of some economies could not be extrapolated to the future global economy. The quality of the environmental data was also mentioned as unsatisfactory and this could be a cause for the occurrence of heteroskedasticity issues. The authors suggested that the analysis of the relationship between the growth and the environment should be based on the historical experience of individual countries.

Since sustainable development is the leading strategy of current development, according to the authors, the EKC is a narrow view which could not help to design the sustainable policy. The authors noted that the previous studies had the main features as follows:

1. A reduced–form equation was used with a possible exception for the time trend, and no extra explanatory variables were included.
2. The analyses were usually conducted based on a panel data set on individual countries.
3. The considered functional relationship was either linear or log–linear.
4. The estimation technique was typically the least squares dummy variable method, allowing for the fixed country and time effect.

Hence, the critical evaluation of the analysed studies leads to conclusion, that EKC concept might be useful tool for testing special factors.

From the studies of the 20th century it can be seen that the EKC relationship between environmental indicators and economic growth has left many questions and areas for further research. It can be seen that, in spite of the great number of investigations, there is no definite answer to the question about the EKC existence and the causes of its occurrence.

1.2.2. The Evaluation of the Studies Conducted in 1996–2005

Further analysis of the empirical studies will be concentrated on the relationship between the air quality, which captures CO_2 emission, and economic growth. It has been decided to use GHG for empirical validation in this research. The relationship between carbon dioxide and economic growth was first analysed by the World Bank (see Chapter 2.1.), and the results of the research showed the increasing trends. In 1997, Roberts and Grims presented the research covering the data from 1962 to 1991 for groups of the countries which, in 1970, had been referred by the World Bank to high, middle and low levels according to income levels. The researchers used the environmental indicator called by them National Carbon Intensity, which was based on carbon intensity divided by GDP. This variable was taken as the log dependable in the quadratic regression analysis. The authors checked if there had been an inverted U – curve relationship for CO_2 emissions per unit of GDP across the period of 30 years and tracked the changes in the selected groups of the countries. The authors thought that the existence of the inverted U – curve for CO_2 emissions intensity would suggest that the pollution reduction might be expected to occur as a natural by–product of economic development, improving the efficiency, particularly, in energy consumption. They expected that their analysis would help to assess the causal importance of abatement policies, the improvement in technical production efficiency and the reallocation of energy and pollution intensive industries to poorer countries. Their analysis showed that the relationship between National Carbon Intensity and GDP changed from the essentially linear in 1965 to strongly curvilinear in 1990 for all countries. Hence, they proved the existence of the inverted – U relationship. Examining the path of National Carbon Intensity in different groups of countries for the selected period, they noticed that the higher income countries demonstrated a decrease in CO_2 emission, while other groups showed its increase. They concluded that the appearance of the significant curvilinear relationship in CO_2/GDP in 1982 was due to the efficiency improvements in the rich countries and worse performance in the poor–and middle–income nations. Based on their research, they determined that other social and political factors were important. The authors thought that most countries would not follow the example of European and North American countries in their development because the theories, involving the development stages of these countries, were inconsistent with the historical record. They confirmed that the analysis of CO_2 emissions could not be based on the development stages as there were no reasons to believe that most countries would ever reach the hypothesized turning point. The wealthy countries specialized in services, while energy−intensive industries tended to concentrate in some poorer countries. Higher polluting industries are moving to the Third World to avoid tougher regulation used in the wealthy countries. The overall picture over the past 30 years suggested that some wealthy countries were decreasing their carbon dioxide intensity, while most of other states were increasing it. They suggested that the sustainability might be implemented at all levels of development. They also mentioned that firms and countries around the world were discovering that it was cheaper to avoid environmental pollution than to clean it up later. They believed that effective international environmental standards and enforcement mechanisms would help in managing the environmental issues (Roberts, Grims 1997).

The authors analysing the EKC behaviour raised the question if the phenomenon of the decreasing pollution in the countries with a higher income was the result of economic growth or there were some other underlying changes. The researchers could not find any convincing evidence that all countries could replicate the experience of the presently industrialized countries. They were reflecting whether EKC was a useful model for the analysis for policy determining the development purposes. Had the highlighting of the turning points been so valuable? Was it possible to replicate the best practice without reaching a certain level of income? In an effort to evaluate whether income was the determining variable, the authors had applied the techniques of nonlinear dynamical analysis. According to the authors, the research into these techniques was known as the "chaos" studies because the latter were characterised by multiple or even an infinitive number of solutions. The authors generated phase diagrams for sixteen countries. The analysis showed that there was a group of countries that demonstrated EKC−like behaviour because the emissions first rose, and then stabilized around an attractor in the period of 1970 to 1980, or declined as the income grew. After analysing many cases, the authors concluded that it was inappropriate to choose a single income turning point because CO_2 emissions originated almost entirely from fossil fuel usage, but, in 1970, the oil crisis led to the decrease of the level of emission. In the case of France, it induced to change the electric power production from coal to a program of the combined nuclear electric power and efficiency gains. These results indicated temporal, historic events and confirmed that it was not the reaching of a given income level, that was at the root of this transition. The nonlinear systems dynamics in the emissions data suggested that the changes in CO_2 emissions trajectories could be based on some shocks or special events in the socio−economic systems. The shocks appeared to provide a sufficient incentive for new policy initiatives, both at the private and public level. The other important aspect which was mentioned by the authors was the speed at which these systems or policies could alter their trajectories. The one–year period was found to be sufficient for such changes. This demonstrated a national capacity for rapid and persistent change under the appropriate stimuli. The authors believed that EKC demonstrated a response to the historical event rather than the income effect. The authors suggested several reasons to explain why the EKC methodology produced conclusions which were different from the results of the analyses. Firstly, the EKC methodology might miss the fact that transitions began almost simultaneously as a result of exogenous factors influence the research demonstrated that the actual behaviour of individual pollution trajectories depended on a combination of internal policy decisions and exogenous factors. Hence, the choice of policy and prices of resources were the principal causes of these transitions. Wealth might be a factor that allowed the countries to move ahead rapidly (Unruh, Moomaw 1998).

The researchers used a panel data model for 110 countries to estimate the relationship between CO_2 and GDP and to forecast emissions in the period of 1971 to 1996. The sample covered 88% of the CO_2 emissions generated by fuel combustion. The authors chose a non–linear functional form, which was known in the statistical literature as Gamma–Weibull function. They motivated their choice by the fact that this decision does not restrain the range of possible shapes. Besides, it better performed econometrically, outperforming the log–linear specification, as a preferable method, on statistical testing groups. In the first part of the study, the estimated results confirmed the EKC hypothesis. In the second part, the researchers forecast the level of emission until 2020. They mentioned that the main advantage of forecasting based on the environmental Kuznets curve was its simplicity. Their prediction showed that the future global emissions would grow, but they emphasized that, in many cases, their projections predicted a lower level of total emissions. The authors advised to create effective technological cooperation (Galeotti, Lanza 1999).

Chapter 2.2 containing this observation will be finished with a review of two influential articles, where the authors summarized the investigations performed in the EKC area.

Based on the reviewed studies, Stern (2004) concluded that there was no simple and predictable relationship between pollution and per capita income. The EKC concept was criticised in two aspects – the economic point of view and the assumptions for the hypothesis and econometric methodology for empirical research. Based on the analysis of the main studies, the authors concluded that some problems of EKC estimation still remained. Stern (2004) classified the theoretical errors in the latest studies into four groups:

1. The income is assumed to be an independent variable, therefore, there is no feedback from the environment degradation to GDP.
2. Trade impact and regulatory differences are not estimated.

3. Transition to new pollutants is not discussed.

4. Unequal distribution of income per capita, with a large number of people below the mean, makes the median, but not the mean, a more relevant variable.

The researchers noticed that EKC was built on the economic assumption, where there was no feedback from the state of the environment to the economic growth because the income was assumed to be an exogenous variable. The decreased quality of the environment might lead to a decrease in the quality of life, but not the production possibilities, and would not reduce the level of income in the future, if we assume that economy is sustainable. Without this assumption, the maximisation of growth could be presented as the best solution for countries, which may lead to unsustainable growth. This statement sounds as the support and the critical need for further analysis of the sustainable development concept. The authors mentioned that the environmental problems could not be solved separately because other social aspects are also very important.

According to the authors, the changes in trade relationship associated with development were not included in the previous models. The neutral effect of trade in the models leads to fundamental problems of the EKC hypothesis. The countries importing raw materials might be exporting the environmental impacts to the trade partners. Stronger environmental regulations may promote further incentives to move the polluting activities to the developing countries, which would find it harder to reduce emissions in the future. Moreover, in order to increase the competitiveness, these countries may preclude further tightening of environment regulations.

While, historically, emissions of many pollutants per unit of output declined over time, the range of pollutants have widened as new pollutants appeared. Hence, the aggregate waste might not have declined. He mentioned that new pollutants, such as carbon dioxide, did not demonstrate the EKC relationship. In our days, efforts are being made to overcome this problem by presenting, for example, the basket of gases which cause the climate change.

Since some researchers have found that the turning points for some environmental indicators might be around the current world mean per capita income, and, therefore, might start declining in the future, however, due to uneven income distribution, the median rather than the mean value is more relevant as a critical variable.

In this work, the provided econometric criticism of the EKC included four main issues as follows: 1. Heteroskedasticity. 2. Simultaneity. 3. The omitted variable bias. 4. Cointegration.

Heteroskedasticity. Stern (2004) cited some authors who found that regression residuals from OLS were heteroskedastic, with smaller residuals associated with a higher total GDP and population. Adjusting for heteroskedasticity in the estimation significantly improved the goodness of fit of globally aggregated fitted emissions to actual emissions.

Simultaneity. Some researchers tested for Granger Causality between the environmental variable and income. The overall pattern that emerges is that causality runs from income to emissions or there is no significant relationship in the developing countries, while, in the developed countries, causality runs from emissions to income.

The omitted variable bias. The omitted variable bias in estimating the EKC relationship at different stages was tested, using this evidence. The differences between the parameters were obtained of the models of random effects and fixed effects using Hausman tests, ii differences in the estimated coefficients of subsamples and iii test for serial correlation. The authors found that the first and the second tests were passed by the OECD (the developed) countries, but there still existed a serial correlation indicated by a high first–order autoregressive parameter. For non–OECD countries, all three tests failed.

Cointegration. Testing for cointegration, the researchers found that the results referring to about the half of individual countries were cointegrated. Even when cointegration was found, the form of EKC relationship varied among the countries dramatically.

Based on various lines of evidence, various suites have found the EKC to be a fragile model, specifically, when applied to the countries at different development stages. It was noted that better model specification, inclusion of additional variables or other methods of analysis might be used to improve the econometric parameters or EKC relationship

The authors noticed that the estimate based on a single equation did not define the different causal chains and could not be the main instrument of a sustainable development policy, which was characterised by many different criteria. A structural model might be more suitable than a single regression. The authors concluded that the historical experience of some economies could not be extrapolated to the global future economy. The quality of the environmental data was also mentioned as unsatisfied and it might be the reason of heteroskedasticity issues. The authors believed that the analysis of the relationship between the growth and the environment should be based on the historical experience of individual countries. Though the sustainable development is the leading strategy now and the EKC, according to the authors, cannot be the only tool to design the sustainable policy (Stern, 2004).

Dinda was a scientist who also tried to summarise the studies of EKC of the 20^{th} century. Dinda briefly described the EKC as a statistical artefact that summarizes a few important aspects of the collective human behaviour in two–dimensional space. It was like a dynamic development process of a single economy that grows through the change of different development stages in a long period of time. Dinda highlighted several factors which could be responsible for shaping the EKC: 1. income elasticity of environmental quality demand; 2. scale, technological and composition effects; 3. international trade; 4. the market mechanism; and 5. regulation. Each of these five factors was explained, considering that other things remained constant (i.e. ceteris paribus).

Income elasticity of the environmental quality demand. It has been assumed that the environmental quality is a luxury good, which is valued by rich people. Hence, income elasticity of the environmental quality demand is higher than one, but the relation of the environmental degradation to income is less than one. According to the author, many researchers highlighted the role of income elasticity of the environmental quality demand and it was presented as a reason for explaining the reduction of the emission level. According to the researchers, in the whole society, poor people do not care about the environmental quality. When a society becomes richer, the citizens start to pay more attention to the clean environment, investing into green products and forcing a strict regulation. Such expectations induce the institutional structural reforms at the local and national levels and the changes in market patterns.

Scale, technological and composition effects. Richer economies produce and consume more. These phenomena referring to the economic growth increase the consumption of resources and cause higher waste. The scale is harmful for the environmental quality. The composition effect brings the changes in the structure of the economy which starts to produce cleaner products and services and develop knowledge–based technology–intensive industry. Technological effects are related to the level of investment through R&D, and are followed by positive changes in technologies. Technological and composition effects outweigh the scale effect in the EKC theory.

International trade. Trade is the main cause of scale of the economies ceteris paribus. The author divided the main hypotheses related to trade into several subgroups. The first one is widely known as the Pollution Haven hypothesis. In richer countries, the demand for the environmental quality is high and the environment regulations are strict. Such business environment forces dirty industries to move to other countries with weak regulations. Many scientists supported the statement that poor countries are concentrated on dirty and material– intensive production, while richer countries specialize in clean and service–intensive production, without altering consumption patterns. On the other hand, direct foreign investments are very important for the development of poor countries, while a low level of regulations is presented as an advantage for foreign investors. Rising capital outflows force the governments in rich countries to begin reforming their regulation system. Despite that, many argue that international trade enhances diffusion of clean technologies. It can be seen that there were wide discussions about the trade effect, and Dinda tried to sum them up. But it was not the end of the discussion and the debates have been continuing in the 21th century.

The market mechanism. Economic development might strengthen the market mechanism, which can help to move to cleaner economy. The increased price of natural resources reduces their consumption and accelerates the shift toward less resource–intensive technologies. The role of oil and gas prices inspired many researchers to include them into the influential factors in the EKC hypothesis. The environmental awareness of various economic agents can change the production and consumption patterns. Information accessibility might play the important role to curve down the pollution level through proper regulation.

Regulation. Regulation is the instrument to manage the pollution level. The form of regulation is moving from command–and–control policies to market–oriented forms of regulation. The scientist highlighted the informal regulation, where the local societies had the influential power to impact the pollution level of their region. The level of property rights impacts the efficiency of resource allocation.

Dinda summarized the results obtained in the analysis and presented his evaluation of the main findings, which could be useful for further studies. Firstly, he emphasized, that many researchers found the EKC for local pollutants, which have local impacts. Most of the EKC studies concluded that the EKC level was affected significantly by ceteris paribus and by national and local policies. It was believed that fruitful analysis could be based on the examination of the historical experience of individual countries. The analysed sources of EKC were classified into two major groups based on structural changes and technological progress. Structural changes comprised such factors as production structure, migration from the areas with high environmental problems, the sectorial structure, the external important events like oil crises and the corruption level. Technological progress embodied the level of R&D and innovation at all stages of the considered processes (Dinda 2004).

As well as the researchers of the 20th century, the scientists of the 21th century were also interested in economic growth and the environmental quality. However, researchers highlighted that the analyses of the relationship between economic growth and carbon dioxide could not be based on the development stages as there were no reasons to believe that most countries would ever reach the hypothesized turning point. They highlighted that such factors as effective technologies, the reallocation of energy and pollution intensive industries to poorer countries, the choice of policy, prices of resources and special shocks impacted the level of GHG in a particular state. Hence, international cooperation is very important in implementing international environmental standards and enforcement mechanisms, which could be effective instrument in managing the climate change issue round the world.

1.2.3. The Evaluation of the Studies Conducted in 2005 and Later

In the last decade, the main problems considered in the EKC literature have not changed considerably. One of the most interesting critical observations was presented by Carson (2010). Therefore, the chapter begins with the analysis of this article.

Analysing the literature on the EKC hypothesis, Carson (2010) pointed out the aspects that were not widely cited in other literature. He highlighted that famous EKC researchers, such as Grossman and Krueger (1991), had not cited the famous books, such as "The Limits to Growth" and "The Population Bomb" (presented in Chapter 1). The EKC theory limited itself by not including the environmental economists' studies. The EKC was promoted by trade/development economists in the context of an international trade agreement rather than by environmental/resources economists in the pollution control context. The author noticed that, after emerging of the EKC studies, the economic growth per person began to be touted as the answer to environmental problems in popular publications. Nobody cared that environment policy was highlighted as the main prerequisite.

Analysing the theoretical literature on the EKC, Carson (2010) analysed the empirical issues and evidences presented by the observed theories based on the data collected for Mexico, the United States, Malaysia and China. He contributed to other EKC critique by noting that the pollution data used in EKC studies were not as comparable across countries as one might hope because different methods and procedures might have been used in each country. He also concluded that the environmental data were very poor in quality.

Econometric issues of the EKC were presented as suspect and fragile. Statistical tests usually rejected random effects specification due to the correlation between the random effects and the included covariates. The fundamental problem was formulated as the need to show causality between income and the environmental variables of interest. The cubic function trend to income led to the conclusion that the environmental conditions eventually took a turn for the worse with the income increase.

The main critique of a general EKC framework is focused on the fact that, for some time, this theory made it easy to believe that the developing countries may grow out from the environmental problems, while, in reality, the developing countries can take many active actions to improve the environment conditions. While there are many articles focusing on the EKC theory, only few have a serious look on how changes in regulatory systems and incentives placed across political jurisdictions could be used to improve the environmental quality and avoid unnecessary environment degradation (Carson, 2010).

Galeotti *et al.* (1991), set themselves a task to reassess the robustness of the EKC for CO_2 emissions by performing the analysis in a different parametric setup and using the alternative emission data supplied by the International Energy Agency. The study used the data from the international Energy Agency and covered the period of 1960 to 1998. The authors highlighted that other researchers used the data from the Carbon Dioxide Information Analysis Centre of the Oak Ridge National Laboratory that covered CO_2 from fossil fuel burning, cement production and gas flaring on the global, regional and national scale. The data were calculated based on methodologies used by the United Nations and the U.S. Department of Energy. The authors detailed the differences between two sources and noted that the data might be more precise because they used specific emission coefficients for different energy products. Despite that the numbers used by them were larger, the differences were not significant. The economic indicators were taken from the OECD Main Economic Indicators, while others used the World Bank database. The sample was divided into high−income (OECD) countries and low−income (non−OECD) countries. The estimation based on two different data sources (panel data) was made by using a standard cubic log−linear EKC relationship for the comparable number of the countries and the period. The obtained coefficients were rather stable across two data sets. Some differences were noticed with the non−OECD group. The EKC was observed for the OECD countries. The non−OECD sample was characterized by the increasing slightly concave relationship. For the second check of robustness, they proposed an alternative functional form with some appealing features. They employed a three−parameter Weibull function. Graphically presented results demonstrated a bell−shaped curve with reasonable turning points for the group of the OECD countries and a less pronounced curve without reasonable turning points for the non−OECD countries (Galeotti *et al.* 2006).

Fosten *et al.* (2012) considered the emissions of gases with respect to the environmental Kuznets curve relationship in the United Kingdom. The analysis of the data was based on the relationship between the emissions of CO_2 and SO_2 gases and GDP per capita. The sample covered the data from 1830 to 2003 for the CO_2 model and from 1850 to 2002 for the SO_2 model. The research showed that long−run results were in favour of the EKC hypothesis, with per capita CO_2 and SO_2 emissions, having an inverse−U relation with real GDP per capita. Furthermore, the short−run error correction models revealed that disequilibrium was corrected solely by changes in per capita emissions, and not by the movements in real GDP per capita. This suggests that mitigating of CO_2 or greenhouse gas emissions and SO_2 emissions will rely more on legislation than the reductions in economic growth. The researchers also used the gas price as the additional variable, which had partially explained the results. The authors suggested that the EKC model should be estimated by specifying and incorporating different measures of technological changes.

Esteve and Tamarit (2012) renewed the research for EKC evidence in Spain, using a linear integrated regression model with multiple structural changes. The authors used time−series data on the Spanish economy spanning from 1857 to 2007. In order to avoid the econometric problems mentioned in previous empirical literature, the authors made use of recent developments in cointegrated regression models with multiple structural changes. They emphasized that the turning point in Spain was dated by 1986 and could be explained by the oil crisis of the 70s, caused by the political instability at the end of the Spanish dictatorship in 1975–78, and by the shift in the energy mix that took place only at the beginning of the 80s. The coefficient of the relationship estimated between per−capita CO_2 and per−capita income (or long−run elasticity) in the presented model showed a tendency to decrease over time. They found that the "income elasticity "coefficient with regard to CO_2 was smaller than one. This implies that even if the shape of the EKC does not follow an inverted U, it shows a decreasing growth path, pointing to a prospective turning point.

Franklin and Ruth (2012) contributed to time series studies, using the U.S. CO_2 emissions in the additional explanation of the potential impact of population and the economic structure. The researchers used the log squared regression equation. The inverted U−shaped EKC was confirmed by a smaller number of data for a hundred−year period with the variables divided by the population size. The total CO_2 emissions might continue to increase. The results suggested that there were some relevant relationships between the demography and the productive structure of the economy and CO_2 emissions. The authors offered to choose the strategies that foster consumption choices consistent with those seen in a society with high elderly dependency ratios as they would more strongly guarantee the sustainable way.

One stream of the 21^{th} studies of the EKC covers the analyses in different industries in OECD countries. Hidemichi Fujii and Shunsuke Managi (2013) assumed that CO_2 emission for an entire country was unclear and did not show individual industrial characteristics or fuel choices. Following the ideas of economic scale, technology level and composition effects on the shape of the EKC, the authors chose to estimate the EKC relationship separately, controlling these effects by the type of industry and type of fuel. They hypothesized that the EKC relationship between CO_2 and growth would be possible for such industries as the wood, wood products and the paper, pulp and printing industries, which do not use fossil fuels as intermediate fuels and whose product value per weight is lower than that of the others. For other industries, referring, in particular, to steel and metal, which use coal as their main intermediate fuel, CO_2 would increase proportionally with the production growth. They considered that the EKC relationship observed in the previous studies could be explained by industrial structural changes. The authors applied a panel regression analysis, based on quadratic or cubic relationship between CO_2 and GDP, incorporating in the model the type of energy, industry, country, year and specifying energy efficiency (the total energy use per sale) and the variables of the share of each industry in GDP (the share of the industrial sector's value added in the total GDP). It was supposed that these control variables would positively impact CO_2. The industries were chosen based on the data available from the International Energy Agency and the level of CO_2 emissions. It was found that overall CO_2 emissions showed the N−shape trend. The EKC hypothesis was supported by the study of the industries producing wood, wood products, paper and pulp, as well as printing and construction industries. CO2 emissions from coal and oil increased with economic growth in upstream industries. Hence, a conclusion was made that three industries were greener than the nine analysed with respect to CO_2 emissions.

Since the main causes of GHG are associated with energy production and consumption, there are many articles related to this sector, and a journal dedicated to energy−related problems also captures the EKC problem. Tsurumi and Managi (2010) examined the environmental Kuznets curve hypothesis for carbon dioxide, using generalized additive models with a generic flexible functional form, allowing a potentially non−linear non−monotonic relationship. A sample covered 30 OECD countries for the period 1960–2003. The authors classified 30 OECD countries into three groups. The dependent variables covered the log of CO_2, while independent variables covered the real log of GDP per capita. The results imply that economic growth was not sufficient to decrease CO_2 emissions. The first group had a negative slope for the high−income levels, while the second group had a monotonically increasing trend at all income levels, and the third group displayed other trends or had confidence intervals which were too wide to interpret. Their results obtained by these authors suggested that economic growth is not sufficient to decrease CO_2 emissions.

The standard analysis was also performed by the authors from the developing countries. It can be noted that they often followed the research path of the developed countries. For example, the authors from Malaysia tested the EKC hypothesis about the existence of the relationship between the environmental quality (i.e. CO_2, SO_2, BOD, SPM10, and GHG) and GDP in order to find any similarities or differences between two sample groups, including the developed and developing countries in the period from 1961 to

2009. The sample was divided into several parts consistent with the World Bank methodology. The analysis performed was based on panel data analysis and the cubic regression model. The estimation of the coefficients led the authors to the conclusions about the EKC existence. The results revealed that CO_2 and SPM10 were the environmental indicators which demonstrated the existence of the EKC. They showed that the developed countries had higher turning points than those of developing countries and allowed the authors to conclude that a higher economic growth might produce different effects on the environmental quality in different economies (Ahmad *et al.* 2013).

It can be seen that the EKC hypotheses also interested the Chinese researchers. Their studies emphasize the specific behaviour of the EKC in their country compared to that in the developed world. For example, Huang *et al.* (2008) studied 38 industrialized countries in order to test their correspondence to the Kyoto Protocol in this respect. They divided the selected sample of these countries into two parts, including the economies in transition (e.g. Russia, the Baltic States, etc.) and the developed countries (e.g. Norway, Austria, etc.). The authors used time series linear, quadratic and cubic equations. The research revealed that the economic development and GHG in the economies in transition exhibited a hockey−stick curve trend. The statistical analysis of the developed countries did not provide any evidence to support the EKC hypothesis for GHG. The authors emphasized that, to achieve the Kyoto Protocol objectives, the parties should implement the policies, which specifically limit GHG with the aim of retarding the climate change.

Liao and Cao (2013) examined the historical relationship between the economic development and carbon dioxide emission in 132 countries for the period of 1971–2009 and evaluated the robustness of the results based on three criteria: data sources, model specification and estimation methods. They included in their empirical analysis such factors as urbanisation, population density, trade and energy mix. The linear spline econometric model, specified in the functional form and including different covariates, was used. Before choosing the quadratic or cubic functional forms, the authors tested whether the results were sensitive to a different number of segments of income elasticity of CO_2 in order to check the robustness of the income effect. The second step was to test the sensitivity of the results by using some additional factors. Based on the chosen econometric methodology, six models were estimated. It was concluded, that while the economic development continued to drive up CO_2 emission, urbanisation, population density, trade and energy mix would potentially contribute to the reduction of the absolute level of CO_2 per capita emission. The authors noted that their results did not support the inverted−U shape concept, but rather described the trend observed in high income segments as a saturation of trend. As most of the countries are still below some threshold income per capita level, the economic policy mix, helping to foster green technology development and the additional CO_2 emission reduction measures should be implemented to offset a negative stage of income and CO_2 relationship. Otherwise, consistent with a historical trend, poorer countries will still need considerable emission volumes to outweigh their economic backwardness.

Wang (2011) performed a panel data analysis of carbon dioxide emissions and economic growth in 138 countries in the period of 1971–2010. The chosen sample was divided into five quintiles according to the level of CO_2 emissions in every country. By estimating regression, he calculated the elasticity values. The estimation of several models suggested that income elasticity dropped along with raising quintiles. In the process of increasing CO_2 emissions quintiles, the growth of GDP would be higher than CO_2 emissions, with income elasticity decreasing from more than one to below zero. The author performed a panel data analysis to estimate the long−run elasticity relationship, using regression. The empirical results showed that the long−run relationship between the global carbon dioxide emissions and GDP was stable. The paper suggested that the top priority to mitigate global warming should be focusing on the countries with a high economic growth and a strong increase in carbon dioxide emission. If the appropriate technologies and policies of reducing CO_2 emissions could be identified, national income would not have to decline in order to limit emissions.

In Table 1, summarized empirical findings of the later studies, where carbon dioxide or GHG were considered to be the dependable variables of the environmental quality. Some of these studies support the EKC hypothesis.

Table 1. Summarized findings of the studies, where carbon dioxide or GHG represented the environmental quality

Authors	Year	Received functional form	Sample and time period	Model
Shafik and Bandyopadh yay	1992	Monotonically rising	149 countries, 1960–1990	Three different functional forms: log−linear, log−quadratic and, in the most general case, a logarithmic cubic polynomial in GDP per capita.

Holtz–Eakin and Selden	1995	EKC	130 countries, 1951–1986	Nonlinear dynamic system analysis. Time evolving space phase that compares emissions in the previous year with those in the current year.
Roberts and Grims	1997	EKC for high income countries; monotonically rising for low and middle income countries	Constant groups of countries (high, middle and low levels of GDP per capita), 1962–1991	Generic flexible functional form allowing a potentially non–linear non–monotonic relationship.
Unruh and Moomaw	1998	EKC	16 countries, 1950–1992	Quadratic regression analyses.
Galeotti and Lanza	1999	EKC	110 countries, 1960–90	Quadratic regression analyses.
Galeotti *et al.*	2006	EKC for OECD countries, not clear for non–OECD	Countries of the UN Framework Convention on Climate Change for 1960–98;other countries 1971–1998	Panel data, standard cubic log–linear regression analyses.
Huang *et al.*	2008	No clear trend in developed countries, while economies in transition exhibited a hockey–stick curve trend	38 countries, 1990–2003	Time series linear, quadratic and cubic equitations
Tsurumi and Managi	2010	The high–income levels – negative slope, the second group – a monotonically increasing trend, the third group –other trends which are too wide to interpret.	30 OECD countries, 1960–2003	Two models –quadratic and quadratic in the natural logarithms
Wang	2011	EKC	138 countries, 1971–2007	Standard cubic log–linear.
Franklin and Ruth	2012	EKC, but show a "rebound effect", suggesting	United States , 1800–2000	Non–linear functional forms, which in the

		continued upward trend.		statistical literature were known as Gamma−Weibull functions
Fosten *et al.*	2012	EKC	United Kingdom, 1830 to 2003–200	Log−squared regression.
Authors	Year	Received functional form	Sample and time period	Model
Esteve and Tamarit	2012	It shows a decreasing growth path behaviour and an improvement in relative terms.	Spain, 1857 to 2007.	Time series, cubic regression.
Liao and Cao	2013	Trend saturation	132 countries, 1971–2009	Time series, cubic regression.
Fujii and Managi	2013	EKC for paper, pulp, wood, construction; increasing trend in other sectors.	OECD countries, 1970–2005	Panel regression analysis, quadratic or cubic.
Ahmad *et al.*	2013	EKC	Developed and developing countries in the period 1961 to 2009.	Panel data cubic regression.

Source: made by author

Some studies support the EKC hypothesis, while others find a monotonically rising trend. Note that even if the EKC has been proved for emissions per capita, pollution still remains a problem for the following reasons:

1. According to the environmentalists, the population growth is one of the main driving forces behind the environmental decay.
2. Even if emissions are falling, overall concentrations might still be above the assimilative capacity of nature.

The analysed articles can be divided into several groups. Depending on the geographic area analysed, two main data analysis techniques were used: a) time series techniques for a single region or location (Saboori *et al.* 2012; Fosten *et al.* 2012; Esteve, Tamarit 2012; He, Richard 2010; Fodha, Zaghdoud 2010; Akbostanci *et al*. 2009), and b) panel data techniques for the analysis of several regions (Hamit−Haggar 2012; Culas 2012; Akbostanci *et al.* 2009; Huang *et al.* 2008).

The EKC was analysed by a number of Lithuanian scientists, including Remigijus Čiegis, Raimondas Čiegis, D. Štreimikienė and others. Čiegis *et al.* (2007) pointed out that the EKC analysis might allow to determine basic conditions for sustainable development management and to assess the environmental policies, aimed at achieving the sustainable development. Critically reviewing the theoretical and empirical literature on the EKC, the authors emphasize that the way to achieving the environmental sustainability is based on maximizing the delinking process between growth and environmental indicators. They think that the use of the EKC models to forecast future emissions can hardly be appropriate.

The analysis of the impact of the EU pollution reduction strategies on atmospheric emissions in Lithuania was made by Štreimikienė and Bakhyt (2008). The authors developed the Kuznets environmental curve, showing the relationship between SO_2 emissions and GDP/capita for Lithuania in the period of 1980–2015. The researchers concluded that the economic growth is the required precondition for emission reduction, while the main drivers are strict policies, which help to reduce the amount of pollutants. They highlighted that the case study of Lithuania is a good example of effective implementation of the EU policy, which could be observed even at a rather low GDP/capita level, compared to that of the developed Western countries.

Since the 1990's many studies on the EKC have been performed, analysing the relationship between various indicators of environmental degradation and income per capita. The interest area varies for different countries, regions and, sometimes, cities. The results can be divided into several groups including many approvals of the inverted U, some increasing trends and some other tendencies.

The following chapter is dedicated to the theoretical analysis of the possible causes of EKC occurrence.

1.3. The Classification of Causes and Factors of Environmental Kuznets Curve

The environmental Kuznets curve is a reduced form function, which shows the net impact of GDP or income on the chosen environmental indicators. According to Panayotou (1997), economic growth acts as an omnibus variable or a surrogate for a variety of underlying influences, the separate effects of which are obscure. As can be seen from the description of the empirical research presented in the previous chapter, that at the beginning of every study, the researchers gave their theoretical explanation why the analysed function might have a particular form. They agree that the development trajectory for pollution is likely to reflect both market forces and changes in government regulation. As a result, it is reasonable to expect that the economies would pass through "stages of development," in which at least some aspects of the environmental quality first increase and then decrease. As summarised by Čiegis *et al.* (2008), EKC is a development trajectory for a single economy that grows through different stages over time. That is, *ceteris paribus*, in their process of development, individual countries experience income and emission situations lying on one and the same EKC.

Grossman and Krueger (1995) raised three main hypothetical causes, which impacted the EKC shape. The scale of economic activity led to the increase of pollution, but altering of the composition of economic activity and the techniques of production changed the path of pollution. The positive effect of composition and techniques might outweigh the negative effect of scale. These three causes can be mentioned as the classical ones. Selden and Song (1994) made the assumption that industrialization and agricultural modernization might lead to increased pollution, while other factors might cause its decrease. They emphasized the role of the following factors: positive income elasticity for environmental quality, the changes in the patterns of production and consumption, the increasing levels of education and environmental awareness and the development of more open political systems. Holtz−Eakin and Selden (1995) defined that endogenous variables might be the composition of output, regulations and taxes, patterns of urbanization, etc., and some country−specific factors, including climate, geography, resources, land area, etc., which were mentioned as exogenous variables of emissions. Roberts and Grims (1997) pointed out that the wealthy countries specialized in services, while energy−intensive industries tended to concentrate in some poorer countries. They also mentioned that firms and countries around the world were discovering that it was cheaper to avoid environmental pollution than to clean it up later. They believe that effective international environmental standards and enforcement mechanisms would help in managing the environmental issues which depend on industrial structure of a particular country. Unruh and Moomaw (1998) suggested that the changes in CO_2 emissions trajectories could be based on some shocks or special events in the socio−economic systems. The shocks appeared to provide a sufficient incentive for new policy initiatives, both at the private and public level. Another important aspect which was mentioned by the authors was the speed at which these systems or policies could alter their trajectories. The authors believed that EKC demonstrated a response to the historical event rather than the income effect. The research demonstrated that the actual behaviour of individual pollution trajectories depended on a combination of internal policy decisions and exogenous factors. Hence, the policy choice and prices of resources were the principal causes of these transitions. Wealth could be an influential factor that allowed the countries to move rapidly. Dinda

(2005) highlighted several factors which could be responsible for shaping the EKC, which included income elasticity of the environmental quality demand, scale, technological and composition effects, international trade, the market mechanism and regulation. Panatyotou (1997) identified the different types of effects that income has on the environmental quality, or rather different effects of economic development that are transmitted through the income variable. He highlighted the scale of economic activity, the composition or structure of economic activity and the effect of income on the demand and supply of pollution abatement effort. Dasgupta and Maler (1994) argued that the EKC is almost certainly something of a mirage, but since the environmental commodities are presented as luxury goods, which have more demand with increasing income levels, the EKC could explain the relationship between economic growth and the environment. They noticed that poor countries could not buy clean technologies because they were expensive and tended to absorb the environmental risk. Such findings are in part related to the research on income elasticity of the demand for luxury goods. Lieb (2004) summarised different influential theoretical studies of the 20th age and systemised possible causes of the EKC. He defined the theoretical causes and the arguments of the EKC form as follows: demand for environmental quality, substitution between pollutants, technological progress, increasing returns to scale in abatement, migration of dirty industries, shocks, income distribution, structural change and shocks. In the latest studies, theoretical causes are defined in groups: equity of income distribution, international trade and pollution heaven, structural change and technological progress, institutional framework and governance and consumers' preferences (Kaika, Zervas 2013). Following the above logic, researchers used various additional proxy variables to prove empirically their positive or negative impact on the relationship between pollution and GDP. To empirically analyse whether or not additional factors are important researchers have expanded the quadratic and cubic equations by adding some additional variables. The latest studies suggested to group these variables into economical, demographic and governance areas (Buehn *et al.* 2013; Gassebner 2011; Lamla 2009).

Based on the empirical studies, general theoretical causes and factors affecting the relationship between the environment indicators and economic activity might be divided into several topics:

1. Scale of economic activity.
2. The structure of economy.
3. Technological development.
4. International trade and the pollution haven hypothesis.
5. Income inequality of income distribution.
6. Political−governance factors.

7. Social–demographical factors.
8. Historical events or shocks.
9. Country–specific factors.

All these causes are interrelated, when some particular cases are analysed, it is difficult to identify which one is the main. The scale of economic activity, composition of economy and technological development are impacting the environment through the economic growth and are often mentioned by researchers as the main ones. If the scale of economy activity leads to a negative impact, technological development and change in the structure of economy have, in general, a positive impact and outweigh the negative impact by economic growth.

The main economic indicator, capturing human activities, is GDP. The structure of economy can change because of changing consumer preferences, as well as because of different rates of technological progress in different branches of the economy and policy–induced price increases for polluting inputs in production in general these changes occur in the country's course of economic development. Rostow (1960) was first, who suggested dividing the process of economic development into five stages, which every nation passes regardless of its social and political structure. In the EKC studies, the course of the economic development is divided into three stages: primary sector changing from agriculture to industrial economy and to service economy. It is assumed that society shifts from the more material and energy–intensive manufacturing sector towards the more environmentally friendly services sector in the course of economic growth (Panayotou 2003). In 1993, Ekins forecasted that the term 'sustainable development' might be realised as the mere development of and implementation of eco–technologies.

The main sources of pollution are associated with the sectors of energy, transport, industry, agriculture, and waste disposal, while forestation has a positive effect on the greenhouse gas level. The economic structure and, specifically, industrialization are very important factors, which might negatively affect the quality of environmental indicators. Researchers used various indicators referring to the economic structure the capital–abundance ratio (K/L) (He and Wang 2012), the percent of the total output of goods and services provided by the industrial sector (Baodong, Xiaokun 2011). The energy sector is defined as the most robust determinant of GHG emission. Researchers used various indicators to evaluate the importance of energy sector's particularities – the high share of electricity production from coal and oil sources in the total electricity production (Lamla 2009). Many studies emphasize the significant effect of technology and structural changes on CO_2 emissions overtime (Lindmark 2002; Kander 2005; Lantz, Feng 2006; Tol *et al.* 2009). Hence, the technological progress is linked to economic growth and green growth might be based on environmental friendly technologies.

International trade impacts the economic growth, leading to the above mentioned consequences. This cause is interrelated with the scale, the technique and the composition effects. The scale effect likely increase in pollution resulting from the economic growth generated by increased market access. The technique effect refers to the changing techniques of production that are likely to accompany liberalized trade. The composition effect refers to the changing composition of an economy that may occur following an episode of trade liberalization as countries increasingly specialize in activities in which they enjoy a comparative advantage (Cole 2004). Trade possibly contributes to increased emissions at a decreasing rate as income rises, but only over certain periods of time (Panayotou *et al.* 2000). Its effect is also related to the comparative advantage of international trade (Pollution Heaven hypothesis), which may lead to the migration of dirty industries out of rich countries into middle or poor income countries. The possible cause of the EKC in developed countries is that dirty industries migrate out of rich into middle income countries (where the infrastructure is sufficiently developed in contrast to poor countries). Copeland and Taylor (1994; 1997; 2005) analysed the North–South trade model to examine linkages between pollution and international trade and showed that free trade improves the developed countries' environment while the developing countries' environment exacerbated. Bilateral trade regressions results show that poorer, non−democratic nations are not US pollution havens (Kahn 2003). In a similar study, the Southern Africa Customs Union was analysed if it may serve as a pollution haven for USA and UK over time but there is a general shift of manufacturing from the latter to the former, which does not include only the pollution−intensive industries (Nahman, Antrobus 2005). Peters *et al.* (2011) noted that the net emissions transfers from developing to developed countries have increased in 2008 which implies that the transfer of emissions through international trade often exceeds the reduction of emissions at a single developed-country level. In the European Union case, imports of energy−intensive goods from poorer countries seem to increase when more stringent environmental standards are applied in the EU indicating the increase of such industries in developing countries (Cave, Blomquist 2008). Researchers used the ratio of total export and import to total GDP, foreign direct investment to evaluate the impact of international trade (Lau et al. 2014; Ren et al. 2014, Shahbaz et al. 2013, Jayanthakumaran, Liu 2012; Onafowora, Owoye 2014; Wong, Lewis 2013; Kearsley, Riddel 2010; Narayan, Narayan 2010). In related theme, the substitution between pollutants covers the arguments that the downturn of the EKC for one pollutant might also occur because it is substituted with another pollutant.

The effect of income inequality for the environment is explained by the notion that, when citizens achieve relatively high standard of living, they are keen to value higher standards of preserving natural environment. Rising income impacts people to support the environmental policies and vote for policies which should improve environment. Income distribution refers to the differences of preferences for environmental quality could depend on the income level. According to Cantore and Padillia (2010), there is a robust correlation between income inequality and emissions distribution and, possibly, the differences in GDP per capita between rich and poor regions are significant determinants of emission distribution among countries. In such kind of studies researchers used the additional variable Gini coefficient of income inequality (Coondoo, Dinda 2008; Bimonte 2002; Heerink *et al.* 2001; Magnani 2000; Torras, Boyce 1998). However, results indicate that the income elasticity of the willingness to pay is close to unity for all income groups implying that becoming richer does not necessarily leads to cleaner environments (Martini, Tiezzi, 2010). The richest households are not most in favour of strict environmental regulations. In fact, the middle classes are most supportive of strict environmental policies. On the other hand, new generations, which have not been used to habituating natural environment might give the preferences to luxury human made capital rather than natural environment.

Political−governance factors covering the development of more open political systems, regulations, effective international environmental standards and enforcement mechanisms might lead to prevention of environmental degradation resulting from the continuing economic growth. These factors are strengthening through political institutions with economic growth and represent the mixed economy, where market externalities are corrected by political forces. Governance factors cover the governance and the quality of institutions. Researches used such variables as composite index measuring quality of political rights and civil liberties (Lin, Liscow 2013), other variables measuring whether or not the party of the chief executive has a left−wing orientation as well as the form of government − dictatorship or democracy as well as democracy index (Wong, Lewis 2013; Gassebner 2011; Mills, Waite 2009), the level of corruption (Cole 2007), the ratio of government environmental staff to total number of governmental staff (He, Wang 2012) and others.

Data associated with age, sex, birth, death, income, nationality, religion, race, or other factors, education, location and other features representing a multicultural society with dominant personal characteristics define the social – demographical situation of an economy. They are defined as socioeconomic characteristics of population expressed statistically. Education level and income inequality are the factors that positively affect the environmental quality. Researchers suggested that there were some relevant relationships between the demography and the productive structure of the economy and environmental degradation (Franklin, Ruth, 2012). The researchers highlighted the ratio of youth dependency and elderly dependency; average years of schooling in the adult population; the level of urbanisation, the levels of education, patterns of urbanization and others might impact attitude to the quality of the environment (Onafowora, Owoye 2014; Buehn 2013; Franklin, Ruth 2012; Lantz, Feng 2006; Managi, Jena 2008; Cole, Neumayer 2004; Lantz 2002; Shukla, Parikh 1992).

According to Lieb (2004), the shocks are at the root of the EKC, when the future path of pollution cannot be predicted. Shocks can lead to reduction of pollution. Shocks might result from price changes, policy measures or technological innovations. The appropriate policy measures include the removal of energy subsidies, the introduction of more secure property rights over natural resources and the internalization of externalities. The authors believed that EKC demonstrated a response to the historical events rather than the income effect. Another study results indicate that the rising oil price during the 1970s might have been more important for the turning point of the EKC for CO_2 than income (Unruh, Moomaw 1998).

Country–specific factors, capturing climate, geography, resources, land area, etc., have an impact on the level of environmental degradation and are widely used as additional factors in many studies.

Based on performed studies general theoretical factors effecting the relationship between environment indicators and economic activity might be grouped in several topics. Systemised theoretical factors and proxy variables referring a particular cause are presented below.

Table 2. Theoretical causes and proxy variables effecting EKC

Theoretical causes and factors	Proxy variables	Researchers and date
Scale of economic activity	GDP or income per capita, per unit of area	All researchers used economic growth as the main factor impacting environment.
The structure of economy	Capital–abundance ratio, industry value added as percentage of GDP, capital–labour ratio, the percent of the total output of goods and services provided by the industrial sector	He, Wang (2012); Baodong, Xiaokun (2011); Tsurumi (2010); Hettige *et al.* (2000); Shen (2006); De Bruyn *et al.* (1998).
Technological development	Energy efficiency; R&D expenditure (or time trend); energy consumption; nuclear energy consumption; the high share of electricity	Onafowora, Owoye (2014); Saboori, Sulaiman (2013); Shahbaz *et al.* (2013) Turner, Hanley (2011); Iwata (2011); Luzzati, Orsini (2009). Brajer *et al.* (2008); Wagner (2010);

	production from coal and oil sources in the total electricity production	Okada, Samreth (2010); Marrero (2010); Lamla (2009); Lantz, Feng (2006); Richmond, Kaufmann, (2006); Lantz (2002); Lindmark (2002); De Bruyn *et al.* (1998); Suri, Chapman (1998).
International trade	Ratio of total export and import to total GDP, foreign direct investment, imports of energy intensity goods in developing countries	Lau *et al.* (2014);Ren *et al.* (2014), Shahbaz *et al.* (2013), Jayanthakumaran, Liu (2012); Onafowora, Owoye (2014); Wong, Lewis (2013); Kearsley, Riddel (2010); Narayan, Narayan 2010, Cave, Blomquist (2008); Aldy (2005; 2007).
Income inequality of income distribution	Gini coefficient of inequality in income distribution	Coondoo, Dinda (2008); Bimonte (2002); Heerink *et al*. (2001); Magnani (2000); Torras and Boyce (1998).
Political–governance factors	Composite index measuring quality of bureaucracy, corruption in governance and democratic accountability; composite index measuring quality of political rights and civil liberties; whether or not the party of the chief executive has a left–wing orientation; what form of government – dictatorship or democracy; the percentage of environmental staff over that of total government staff	Lin, Liscow, (2013); Wong, Lewis (2013); Fosten *et al.* (2012); Gassebner (2011); He, Wang (2012); Cole (2007), Lomborg, Pope (2003); Mills, Waite (2009); Michael, Nieswiadomy (2005); Neumayer, (2004); Bhattarai, Hammig (2001); Barrett (2000).
Social–demographical factors	Population density; youth dependency and elderly dependency ratio; average years of schooling in the adult population; the level of urbanisation	Onafowora, Owoye (2014); Buehn (2013); Franklin, Ruth (2012); Lantz, Feng (2006); Managi, Jena (2008); Cole, Neumayer (2004); Lantz (2002); Shukla, Parikh (1992).
Historical events or shocks	Price of natural resources, particularly, energy	Agras, Chapman (1997; 1999); Unruh, Moomaw (1998)
Country–specific factors (endowment)	Climate, geography, resources, land area, resource availability etc.	He, Wang (2012); Grossman, Krueger (1995); Holtz–Eakin, Selden (1995); and many others

Source: made by author

The executed systemic analysis of empirical studies, where the EKC analysis was extended to include some additional variables, has led to the notion, that different locations and different time series may be significantly impacted by special factors. The author of this dissertation decided to create the technique to estimate the relationship between economic growth and environmental degradation and empirically test the extended EKC model in the EU countries. This attempt was inspired by other studies, where additional factors, such as energy price and technological level (Fosten 2012), trade openness and population density (Ahmed, Long 2012), as well as the role of the political institutions (Lin, Liscow 2013) were tested. Since climate change is considered to be one of the main environmental issues in today's world, a short look at this issue was made in the following section.

1.4. Conclusions to Chapter 1

1. Environmentalists and other researchers aiming at preservation of the natural environment feel huge hopelessness as the behavioural patterns of human beings as partly biological species and partly social animals are so destructive to natural environment. The concept of sustainable development trying to capture economic, social and environment aspects of humans' life is presented as a direction for development of the world. Despite this direction being strategic aim for forty recent years, the environmental problems are still very serious, and, in many places the natural environment is destroyed beyond repair, supporting the critics that sustain and develop is oxymoron.
2. Since the 1990's, many studies analysing the relationship between various indicators of environmental degradation and income per capita have been performed, giving this relationship a general name of the environmental Kuznets curve. The interest area varies from different countries, regions and, sometimes, cities. In general, econometric techniques split into time series techniques for a single region or location and panel data techniques for the analysis of several regions, using quadratic, cubic or log equitations. In most of the analysed cases the results approved the inverted U relationship, while some indicated the increasing trends or other tendencies. The executed systemic analysis of empirical studies, where the EKC analysis was expended with additional variables, has led to the notion, that different locations and different time series may be significantly impacted by special factors. It should be noted that the EKC approach could not be used as the instrument promoting the economic growth as the solution to the environment problems. It should rather be used for the analysis of policy instruments and additional factors in order to limit the environmental degradation in the course of economic growth, i.e. to reduce the height of the EKC based on the findings from the experience of wealthier

countries and adopting policies that permit “tunnelling” through the curve.

3. Based on the performed studies, general theoretical factors affecting the relationship between the environmental indicators and economic activity might be grouped into several topics: the structure of economy, technological development, international trade and the pollution haven hypothesis, income inequality of income distribution, political−governance factors, social−demographical factors, historical events or shocks and country-specific factors. All these causes are interrelated, when some particular cases are analysed, it is difficult to identify which one is the main. The main indicator representing the economic area is GDP per capita and in the EKC models, some additional variables, e.g. openness of economy, corruption level, educational level and many others (Table 2), are used to empirically check their statistically significant impact on the environmental indicator.

2

The Evaluation of the Impact of Economic Growth on Greenhouse Gas Emissions

The significant problem of simultaneous maintaining of the steady growth rate and slowing down the level of GHG emissions is raised in the European strategy 2020. The EKC concept is one of the approaches used for studying the interaction between the different effects of economic growth and the indicators of environment degradation in the course of the country's development. It can be used for designing the climate change and sustainable development policies. This chapter aims to describe the GHG as a variable representing the environmental quality in further research in the EU context and to present a theoretical technique with the model, assessing the factors, which may have an impact on the GHG level based on the economic theory.

The chapter has the following structure. In Section 1, the climate change phenomena are described from some historical perspective, including measuring, monitoring and controlling of the GHG level in the EU countries. In Section 2, the factors for the model might determining the form of EKC are identified based on the theory of economics. In Section 3, based on the particular aspects of econometrical methodology and logical abstraction of economic theory the technique of the evacuation of the impact of economic growth on the indicators of environmental degradation is presented.

The analysis presented in the chapter can be found in the published articles of the author (Lapinskienė *et al.* 2014; 2013; Lapinskienė, Radavičius 2014; Lapinskienė, Tvaronavičienė 2012; Lapinskienė 2011; Lapinskienė, Tvaronavičienė 2009).

2.1. The Analysis of the Variable 'Greenhouse Gas Emissions'

In today's world, climate change, assumed to be caused by human activities (the so−called anthropogenic effects), is widely discussed and considered to be a major threat to the environment. Over the period of about 150 years (beginning with the industrial revolution), great amounts of carbon dioxide and other gases, producing the so−called greenhouse effect, were released into the atmosphere. Based on the assumption that the harmful effects produced by human activities cause climate change, researchers are trying to find the methods and ways of interrupting this causal relationship between human activities and climate.

The current approach to greenhouse effect has its roots in the nineteenth century and is described in the works of Fourier, Tyndall and Arrhenius. The discovery of the greenhouse effect is not connected with the attempts of scientists to understand global warming. It was made when they were searching for the mechanism that triggered ice ages. This process was started by Joseph Fourier in the 1820s. Later, in 1896, Svante Arrhenius, a Swedish chemist/physicist, who was working with the data on the prehistoric ice ages, was able to discover that the cutting of the amount of CO_2 in the atmosphere by half could lower the temperature over Europe about 7−9^{o}, while roughly the equivalent of this amount would trigger another ice age (Stern 2008; Casper 2010). Charles Keeling set up a CO_2 monitoring station at Mauna Loa, Hawaii in 1957. Since 1958, Keeling has been making measurements of CO_2, which are still continued today and show that the level of CO_2 is rising. Charles Keeling was a true pioneer in establishing the existence of global warming. His work was instrumental in showing scientists world−wide that the CO_2 level in the atmosphere was indeed in the continuous rise. Due to the worthwhile merits and significance of his work, NOAA began monitoring CO_2 levels worldwide in the 1970s (Casper 2010). Mauna Loa Observatory has been continuously monitoring and collecting data related to atmospheric change, including the phenomena of climate change, since the 1950's. Carbon dioxide is not the only gas causing climate change. There are several types of greenhouse gases, which have different properties. The Montreal Protocol controls the production and consumption of specific chemicals, none of which occurs naturally. The formula of the Montreal Protocol targets and timetables has been subsequently employed in the Kyoto Protocol (Montreal Protocol 1987).

According to Hess, climate change can impact human development in five main areas: agricultural production, renewable water supply, coastal population, temperature of the oceans, the expansion of diseases such as malaria and dengue (Hess 2013). The problem of managing greenhouse gases was managed by the creation of the independent unit – the Intergovernmental Panel on Climate Change in 1988. It was open to all member–states of the World Meteorological Organisation and the United Nations Environment Programme. It was the root of the establishment of the United Nations Framework Convention on Climate Change (UNFCCC 2011). According to the Eurostat, the second assessment report of the Intergovernmental Panel on Climate Change's in1995 was a key input to the negotiation of the Kyoto Protocol in 1997 and still remains the basis upon which greenhouse gas emissions data are collected and published. The Kyoto Protocol, the main international agreement which came into force on 16 February 2005, committed the industrialized countries to stabilize GHG emissions. The major feature of the Kyoto Protocol is that it sets the targets for 37 industrialized countries and the European Community to reduce greenhouse gas emissions (Kyoto 1997). The Kyoto Protocol legally binds developed countries to emission reduction targets. The European Union as a party to the United Nations Framework Convention on Climate Change reports annually its greenhouse gas inventory for the year t–2 and within the area covered by its Member States.

According to Stawins (2012), the climate is a public good and climate change is an externality associated with GHG emissions. It evokes expenses that are not paid for by people who create the emissions. Much of economic activity and results in human–induced climate change, which should be corrected through institutional, market or policy intervention. The analysis of the economics of climate change should be global covering the long–time horizons, capturing the economics of risk and uncertainty. This field should be analysed with ethical perspectives, including individual freedoms and rights as well as global paradigms of the separate states' responsibility and welfare.

According to Stern (2004), the features of GHG are follow:

- It is global in its causes and consequences.
- The impacts of climate change are long–term and persistent.
- Uncertainties and risks in economics are pervasive. There is a serious risk of major, irreversible change with non–marginal economic effects.

The practical observation of sources of GHG in European Union based on the statistical guide of GHG emissions in the European Union is presented below (2010). According to Eurostat, human-induced greenhouse gas emissions have been growing at a rapid pace in the last 200 years, reflecting the increases in the world's population, alongside economic development that has resulted in higher levels of production and consumption and the creation of a global economy. The changes in the level of emissions are also reflected by such phenomena as deforestation. Large numbers of countries have begun to make efforts to reduce their greenhouse gas emissions. In the European Union sectors that may contribute to greenhouse gas emissions or removals are grouped as follows:

- land use and agriculture;
- energy;
- business (industry and services);
- transport;
- waste.

Hence, the European Union stated that the prevention of climate change is one of the strategic priorities and encouraged other countries to follow its example. The European Union claimed the reduction of greenhouse gas emissions by at least 20% compared to the levels of 1990 till 2020, then 40−60% till 2040 and 80% till 2050 to be one of its strategic priorities (Europe 2020). It is also monitoring the progress achieved by the EU, its member−states and other EEA member−countries towards their respective targets under the Kyoto Protocol.

Following these political decisions, the Eurostat database presents the GHG indicators. The indicator of "Greenhouse gas emissions" consist of elements of the emitted greenhouse gases as follows: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) (Kyoto 1992). They were aggregated into the variable of greenhouse gas emissions expressed in tonnes as units of CO_2 equivalents. This variable was identified and described in the United Nations Framework Convention on Climate Change, the Kyoto Protocol and the Decision 280/2004/EC and presented in the Eurostat database (Eurostat 2013). The EU greenhouse gas inventory is the most relevant and accurate source of information on greenhouse gas emissions in the EU, and serves to monitor all anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol. The EU inventory is fully consistent with national greenhouse gas inventories compiled by the EU Member States. The amount of greenhouse gases in every country is estimated by combining information of human activity with a coefficient quantifying the emissions from that activity. Such coefficients are termed 'emission factors', and may be used as follows:

Emissions = activity data * emissions factor (Eurostat statistical book 2010).

According the Eurostat, fuel combustion and fugitive emissions accounted for 79.3%, agriculture – 9.2%, waste – 2.8% and industrial processes, solvents &

product use – 8.8%. Every sector has its own characteristics, but there are also some particularities which are common to the whole economy. In the table, given below, the sectors analysis, defining the sources of GHG and factors impacting the level of GHG in each sector is presented based on the EU methodology (Eurostat statistical book 2010). Every country developed its own methodology based on the Eurostat – provided recommendations. Every enterprise can suggest its own methodology for calculating the GHG resulting from their activities. These calculations are audited by independent experts or the Ministry of Environment. In such way the calculated GHG in the national territory are included.

Table 3. The GHG sources and factors influencing the GHG level in the EU member–states

Sector	Main sources	Short–term factors	Long–term factors
Agriculture	Fertilisers livestock emissions stored animal manure rice cultivation	Efficient farming practices, the reduced application of nitrogen-based fertilisers, as well as better forms of manure management.	Changes in land use, soil type, acid rain.
Energy electricity (subsectors–heat production and manufacture of solid fuels)	Fuels (oil, gas, coal) combusted to generate heat or power for energy industries, manufacturing and transport) fugitive emissions	Energy mix, combustion conditions, technologies in use (low–carbon), emission control policies, as well as fuel characteristics. Renewable energy, capture and geological storage, nuclear energy.	Energy demand and consumption patterns, climate change, geographical position, structural changes, environmental legislation, the liberalisation of electricity markets, prices of resources.
Business (industry and services)	Fuel combustion industrial processes and production use commercial/institutional activities chemical processing	Abatement technologies, substitution, improving, tax systems, energy efficiency of transport engine, fuel quality.	Structural changes, eco–friendly products promotion, resource endowments, eco–management and audit scheme (EMAS).
Transport	Combustion of fuels the use of catalytic converters	Abatement technologies, substitution, improving, tax systems, energy efficiency of transport engine, fuel quality.	Rapid growth in passenger numbers travelling, infrastructure mix.

Waste	Solid waste disposal of wastewater discharge from the incineration the open burning of waste.	Waste prevention, followed by reducing waste disposal through reuse, recycling and recovery, technologies, effective waste management.	Waste management policies, waste prevention initiatives, better resource efficiency, sustainable development level, production and consumption patterns, other sectors policies.

Source: The information was grouped by author based on the EU methodology http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-31-09-272/EN/KS-31-09-272-EN.PDF

The Kyoto Protocol restricts the accounting of the LU−LUCF sector, with net emissions relating to forest land management, cropland management, grazing land management and/or vegetation considered as optional in relation to inventory reporting requirements.

As it seen from Table 3, the main source of GHG is combustion of fuels (oil, gas, coal) in sectors (energy electricity and manufacture of solid fuels, business and transport). According to the Eurostat, the main source of GHG is related with energy: fuel combustion and fugitive emissions accounted for 79.3%, agriculture – for 9.2%, waste – for 2.8% and industrial processes, solvents & product use – for 8.8%. There is a range of policy tools according to the type of sources and impacted factors. The EU sustainable energy policy targets (promotion of renewable energy sources, energy efficiency measures, increase of energy security) are targeted in reducing the GHG level.

The data on the total net emission, tonnes of GHG per capita in the selected countries is presented in the Figure 3.

As shown in the Figure 3, Ireland, Denmark, Netherlands, Finland, Germany, Estonia, Belgium and Czech Republic are the countries providing the largest amounts of GHG. They are followed by UK, Poland and Norway. The level of GHG is rather low in the Baltic countries. The carbon dioxide emissions make the largest of part of greenhouse gas emissions in each country. It means that the intensity of energy consumption reflects the carbon intensity of each economy. The countries with dominant energy intensive sectors such as energy and business, release more GHG compared to the countries, importing more energy intensive products like those made of iron and steel. A countries' endowment of resources impacts the energy mix proportion: for example, a relatively high propensity to use coal in Poland and Estonia clearly impacts the level of greenhouse gas emissions per capita. The type of the consumed resources can explain the differences. In general, the structure of the economy influences the GHG level, while the shift towards services reduces the GHG level.

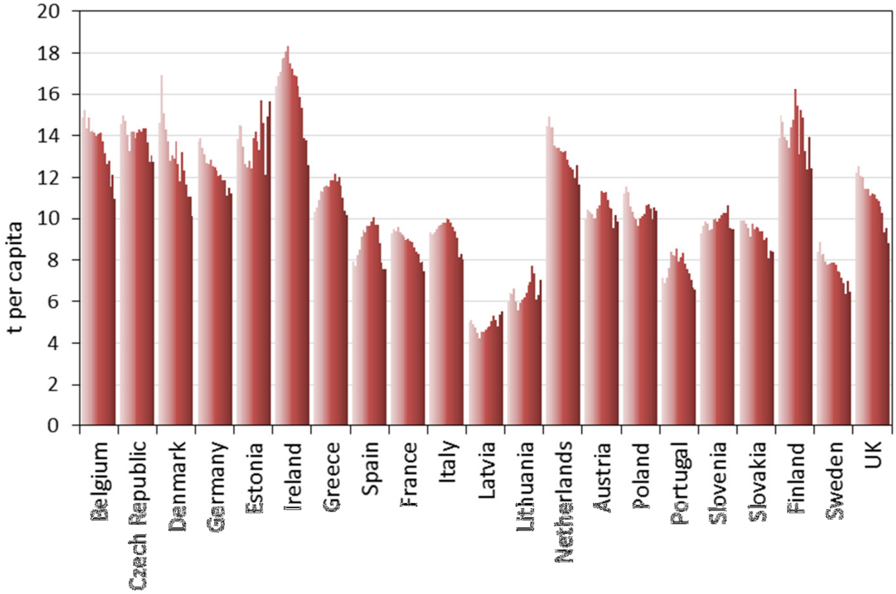


Fig. 3. Dynamics of net emissions in 1995–2011
Made by author (*source*: Eurostat)

Lithuania is one of the 195 countries of the world that have ratified the United Nations Framework Convention on Climate Change. In Lithuania the National GHG inventory report is prepared in accordance with the Updated UNFCCC reporting guidelines on annual inventories. It contains detailed information about Lithuania's emissions by sources and removals by sinks for the period from 1990 to 2011 (National greenhouse gas emission inventory report, 2013). According to this report, the most significant source of greenhouse gas emissions in Lithuania is energy sector with 54.7% share of the total emissions in 2011. Agriculture is the second most significant source and accounted for 23% of the total emissions. Emissions from industrial processes contributed 17.3% of the total greenhouse gas emissions, waste sector – 4.6%. The main contributors in energy sector are Energy industry and Transport sector. In 2011, these sectors composed 37.6% and 37.9% of the total GHG emissions from Energy sector, respectively.

Summing up, the problems related with the climate change are growing in importance and draw international attention. The European Union is the leading region working with this problem and considering its citizens' behaviour the changes arising from changes in the price and contribution of all sectors of the economy as well as new technologies, which might fructify the result to reduce GHG level by 80 percent till 2050. The reduction of GHG by 20 percent is explicitly introduced in the European strategy 2020, but recent improvement in the data in 2008 and 2009, indicating decrease in GHG of above 15 percent is more closely related to the global financial crisis and related decrease in economic activity rather than to any new instruments of the environmental policy.

High divergence in GHG amounts remains among separate EU countries: during last 20 years, Ireland, Denmark, Netherland, Finland, Germany, Estonia, Belgium and Czech Republic are the countries providing the largest amounts of GHG in EU (per capita).

The variable of GHG emissions is chosen as a dependable variable of the environmental characteristics and GDP as an independent variable, capturing economic activities of human beings for creation the model.

2.2. The Identification of Factors Influencing the Interrelationship of Economic Growth and Greenhouse Gas Emissions

The main idea of the reduced EKC model is the direct analysis of the economic growth impact on various environmental indicators. The expanded EKC model analyses the impact of special additional factors and gives a possibility to evaluate the significance of the selected factors. According to Panayotou (1997), shifts in people's preference functions and in social norms are slow adaptive processes that may fall more behind a fast rate of environmental degradation than a slower one which allows time for adaptation and adjustment. Indeed, one reason for the observed inverted−U relationship between environmental degradation and income is the discrepancy between the rates of economic and social change, with the latter always trailing the former. It is assumed that GHG on environmental quality indicator is affected by various factors of economic activity that are mostly referred to the GDP terms. Economic growth leads to higher output and thus to higher pollution ceteris paribus. However, actual income−environment relationship depends not only on GDP itself, but also on various effects of economic and social development (Table 2). In the present research for the chosen sample, the different effects of development has been defined. Five theoretical factors and proxy variables effecting EKC have been chosen for the analysis (Table 4).

Table 4 Chosen theoretical causes and proxy variables referring a particular point effecting EKC

Group Theoretical causes and factors		Proxy variables	Description of proxy variable
Classical causes	The scale of economic activity	GDP per capita	GDP in PPS (Euro per capita)
	The structure of economy	The share of a particular polluting industry	Agriculture+Industry+Construction value added as percentage of total GDP
	Technological development	R&D	Research and experimental development include all expenditures within the enterprise business sector on the national territory during a given period and is shown as a percentage of GDP
Political−governance factors	Economic and fiscal instruments	Environmental taxes	As percent of the total taxes and social contributions
		Energy taxes	Ratio of energy tax revenues to final energy consumption ((Euro per tonne)
Socio−demographical factors	Voluntary activities	ESG score	Percentage of companies that discloses ESG data collected by Bloomberg out of total number of the listed securities for a country

Source: made by author

Three causes (the scale of economic activity, the structure of GDP, technological development) has been chosen as the classical ones, in addition environmental taxes and energy taxes, referring to the policy options, and ESG score presenting the level of sustainable business has been selected.

The GDP and its structure's variables described above gives the proper estimation of the overall wealth and its impact on GHG. As a general rule, the increase in economic activity results in a higher level of environmental degradation, as it requires higher consumption of resources and waste generation. GDP and the rate of its growth refer to the rate of increasing economic activities, which causes the growth of pollution. The environment, either as a production factor or as a consumer good or as a waste sink, can restrict the process of economic growth (Brockand, Taylor 2004; Klassen, Opschoor 1991). In the EKC models, the GDP per capita has been taken as the variable, capturing the raising activities and welfare of the particular state's citizens, which is assumed to impact the form of the EKC. GDP expressed in purchasing power−parity is specifically used in this research for minimizing the potential differences in prices between the countries, which may arise at different stages of development.

According to the Eurostat, GDP includes goods and services, which have (or could have) markets and products, which are produced by the government and non−profit institutions. GDP per capita is calculated as the ratio of GDP to the average population for a specific year. It is often used as the main indicator of the well−being of a country, since it is a measure of the average income in the considered country. GDP expressed in purchasing power−parity is specifically used in this research to minimize the potential differences in prices of the countries, which may be at different stages of development. Usually, various GDP in PPP expressions are taken by researchers as the main independent variables. Selden and Song (1994) took real per capita GDP in 1985 U.S. dollars from the Penn Mark IV World Tables, who used a common methodology for all countries. Galeotti *et al.* (2006) took GDP expressed in 1990 U.S. dollars on the PPP basis taken from the World Bank. Lin and Liscow (2012) used GDP per capita at purchaser's prices in constant 2000 international dollars from the World Development Indicators. A brief remark of Stern on the discussion about the estimation of GDP of different countries and regions and its comparisons is given below. There are two ways of estimating the monetary value of GDP: in market exchange rates or purchasing power parities. According to Stern (2005), there are several evaluation problems associated with market exchange rates. The main problem is related to non−traded goods and services as their prices are not equalized by competition. Since the price of non−tradable goods relative to traded goods and services tends to be higher in rich countries than in poor ones, the ratio of income per head of rich countries to that in poor countries is exaggerated. Thus, the use of this method means that the current GDP levels per head will be underestimated in the developing countries. Using purchasing power parities it is possible to compare real incomes across countries by considering the ability to purchase a standard basket of goods and services, but the PPP have some problems as well. First, such calculations require very detailed information about the prices in national currencies of many comparable goods and services, therefore, only lower frequency data are available. Second, there are different ways of weighting individual countries' prices to obtain international prices and aggregating the volumes of output or expenditure. Hence, the GDP at PPS variable was taken from the Eurostat database (GDP per capita in PPS at current prices). Other potential GDP indicators, such as unadjusted nominal GDP and real GDP, are not considered in the work because its objective is to demonstrate the nominal EKC in order to avoid possible distortions of income inequality. These expressions of GDP may be used in further research. To compare the countries, GHG and GDP were divided by the particular countries' population (Annex A). The variable is taken from the Eurostat database.

The composition of economic activities influences the level of the environmental degradation as the consumption of resources and degradation intensity are different in different sectors of economy. In general, industry tends to be more pollution intensive than the service sector. Therefore, if other factors are held constant, higher GDP levels and a stable economic structure should lead to monotonically rising pollution. Since the structure of economy changes during the economic growth of a country because, at the early stages, the development of agriculture intensifies and, subsequently, the development of industry is accelerated. This causes the growth of pollution and degradation. In later development phases (when a country becomes richer), the service sector develops more rapidly than other sectors, and these changes in the economic structure result in the less polluted environment even at a higher GDP level. Eurostat presented the environmental data on the European Union subdivided into five sectors: energy, transport, business, land use and agriculture and waste (Eurostat statistical book 2010). The structure of the economy changes with GDP variation, and, in many models, a variable reflecting the economic structure refers to the share of a particular polluting industry.

According to Acemoglu (2009), economists normally use the shorthand expression "technology" to capture factors other than physical and human capital that affect economic growth and performance. Technology across countries include not only differences in production techniques and in the quality of machines used in production but also disparities in productive efficiency. It is assumed that improving technologies will lead to better environment without limiting general growth trends. In general, environmental technologies can be classified into three large groups:

1. Clean production technologies, which eliminate the root causes of environmental pollution or reduce their impact.
2. End of–pipe environmental pollution reduction technologies eliminate environmental pollutants from the production process.
3. Climate technologies reduce GHG or separate these gases before release into the environment (Klavinš *et al.* 2010).

Hence, the 21–st century is the age of the biology science and the novelties in this field may lead to higher prosperity and cleaner environment in the future. At the political level, the priorities of the strategy Europe 2020 are about delivering smart and sustainable growth based on effective investments in education, research and innovation leading to a low-carbon economy (Europe 2020). Hence, one of the way to maintain growth and decrease pollution is to develop new technologies, especially those that bring positive economic productivity effects and are also environmentally friendly. After a considerable economic growth, a nation can afford to spend more on R & D for technological development towards green technology (Komen *et al.* 1997). In the context of sustainable development and green economy it assumed that research and experimental development may be more related to environment friendly technologies and processes. The development of cleaner techniques is encouraged by investments in environmental R&D for which, a sufficient level of economic growth is required (Neumayer 1998). In this context, it is assumed that business R&D may impact the GHG and GDP relationship. The variable is taken from the Eurostat database. According to Eurostat database (2013), research and experimental development include all expenditures within the enterprise business sector on the national territory during a given period. Research and experimental development expenditure is shown as a percentage of GDP. On the other side, the direct impact of R&D may be complicated to detach from the overall level of development.

According to Williams, markets do not function effectively if the substantial costs of using our environmental capital are ignored. Polluter–pays principle and the principle of full cost pricing are guidelines to modify markets. Implementing either emissions taxes or emissions permit systems for each significant source of pollution would do much to fulfil the principle of full–cost pricing (Williams 2010). There are policy options for negative externalities. According to Štreimikienė, Plikšnienė (2007), the range of measures according to the type of policy instrument employed, following the categorisation used by the United Nations Convention on Climate Change, are distinguished between: Economic and fiscal instruments; Regulations and standards; Voluntary agreements; Information and awareness; Research and development. The fundamental thing to understand about taxes is that when a tax is present in a market, there are two prices of interest: the price the demander pays and the price the supplier gets (Varian 1990). An efficient market mechanism which ensures the existence of 'self–regulatory market mechanism' for tradable natural resources might prevent environmental degradation. The market mechanism, where prices adjust to equilibrium demand and supply, as the most efficient method for allocating resources. Given the factors underlying the market demand (e.g., number of demanders, average incomes, tastes and preferences, and prices or related goods) and the factors underlying the market supply (e.g., input costs, technology, number of suppliers, and government regulation). A change in any one of these factors would shift the demand or supply curves and upset initial balance in the system. The market would tend to adjust, however, and a new equilibrium would be achieved. Negative externalities occur when a private action, such as the production or consumption of a good or service, imposes costs on society like pollution (Hess 2013).The EU comprises many countries with high income per capita, where the stringency of environmental regulation is one of the highest in the world (according to the competitiveness report, Germany, Switzerland, Norway and Sweden are the leaders). The polluted environment reduces the country's attractiveness to people, who would like to live and work in this country in the longer−term perspective. The newest theories emphasize that the healthy environment is a strong competitive advantage (Porter 2009). However, neither concept can offer an optimal formula and a simple path, leading to balanced development for every country. Nevertheless, to preserve the environment is an important objective not only for the future, but for the current generations as well. Hence, in this context, the economic processes have to be transformed based on ecological processes and should be incorporated in the competitiveness policy. Environmental taxes have been widely used to influence the behaviour of producers or consumers. According to Stamatova and Steurer (2011), the EU has increasingly favoured these instruments because they provide a flexible and cost−effective means for reinforcing the polluter−pays principle and for reaching environmental policy objectives. The use of economic tools for the benefit of the environment is promoted in the Proposal for a new EU Environment Action Programme to 2020 − 7th environment action programme (EAP), the renewed EU sustainable development strategy and the Europe 2020 strategy. According to Eurostat, an environmental tax is one whose tax base is a physical unit (or a proxy of it) of something that has a proven, specific negative impact on the environment. Environmental taxes can be of four types: energy, transport, pollution and resource taxes. Energy taxes include taxes on energy products (e.g. coal, oil products, natural gas and electricity) used for both stationary purposes and transport purposes. Transport taxes mainly include taxes related to the ownership and use of motor vehicles. Pollution and resource taxes cover different types of taxes: taxes on the extraction of raw materials; on measured or estimated emissions to air and water; on noise and on the management of waste (Eurostat 2013). Implicit tax rate on energy (energy taxes) is the ratio of energy tax revenues to final energy consumption calculated for a calendar year. Energy tax revenues are measured in euro (deflated) and the final energy consumption as toe (tonnes of oil equivalent) (Eurostat 2013). In this analysis taxes variables were chosen as a potential policy options for negative externalities. Environmental and energy taxes is one of the factors affecting market mechanism forces playing out in EKC analysis and which can be actively managed by policy makers.

In order to develop in a sustainable manner, it is not enough to have strong regulations, but is very important to attempt to live, respecting the ethical values. It is the reason why responsible voluntary activities are supported and funded by the UN. According to Southworth (2009), corporate voluntary activity plays a key role in balancing environmental protection and economic growth. The level of voluntary activities on a personal or company level are based on many factors, such as the level of education, nationality as well as the level of income, the support instruments, and other issues which are, sometimes, not clearly identifiable. The responsibility ideas are not new in the academic and business world. Since the beginning of the 20th century, there have been many discussions about the contribution of business to the solution of social and environmental problems. Corporate social responsibility, sustainable business and shared value (Idowu 2011; Porter, Kramer 2011; Porter, Kramer 2006) are the theories, which enable enterprises to create the economic value, solving the problem of satisfying social needs and preserving the environment at the same time. After the Earth Summit in 1992 in Rio de Janeiro, the concept of sustainable development was widely accepted by the business world. Business leaders took the challenge of implementing the new concept in business philosophy, strategy and operations in order to contribute to the solution of global problems. Various rules restricting business activities and voluntary initiatives are created in order to maintain the sustainable world. Some examples of non–mandatory approaches to the environment protection and social justice could be the implementation of ISO (International Organization for Standardization) standards or preparation of voluntary reports on business sustainability (Global Compact Network). In the financial market, such performance is reflected in the sustainability indices. A number of independent rating agencies evaluate companies' efforts to be sustainable or green (such indices like The OMX GES Ethical Index and OMX GES Sustainability indices, The Dow Jones Sustainability indices and others). The term which is known in investment world is Environmental, Social and Corporate Governance (ESG) appeared in the United Nations' Principles of Responsible Investment. Since then, the term has become very popular around the investment community and is mostly related to the responsible investment concept (sometimes, synonymously used with the term of socially responsible investment or sustainable investment). In this context, researchers agree that, when firms change their values or objectives based on the increasing social and environmental risk, their strategy and expenditures change and affect the financial results (Les Coleman 2011). Some scientists emphasize that such investments are merely additional costs for business (Friedman 1970; Telle 2006), while other researchers argue that, in the long term, they will help to decrease costs and stimulate the increase in revenues (Heal 2005; McWilliams 2006). Hence, a large number of scholars have approached the issue of corporate responsibility through the lens of corporate financial performance and, thus, are predominantly empirically investigating, where socially responsible performance affects corporate financial performance (Ameer, Othman 2011; Ziegler *et al*. 2011; Ziegler, Schröder 2010; Callan, Thomas 2009; Peloza 2009; Margolis, Walsh 2007).

After the Earth Summit in 1992 in Rio de Janeiro, business leaders took the challenge of implementing the new concept in business philosophy, strategy and operations, in order to contribute to the solution of global problems. Transposing this idea to the business level, corporate sustainability can accordingly be defined as meeting the needs of a firm's direct and indirect stakeholders (such as shareholders, employees, clients, pressure groups, communities, etc.), without compromising its ability to meet the needs of future stakeholders as well (Dyllick *et al.* 2002). It can be said that such concepts originated from business ethics, like corporate responsibility, corporate citizenship and corporate social responsibility (Malovics *et al.* 2008; Shinkle *et al.* 2011). Within ecological modernisation the monitoring and making visible of environmental flows and qualities was believed to be one of the crucial processes for environmental reform. Visualising and articulating environmental interest via information was a key first step in environmental reform of largely invisible environmental flows (Mol 2008). In order to fulfil the lack of qualitative data representing environment preferences in company level, in 2004 Bloomberg has introduced an index which can validate companies' activities in environmental, social and governance (ESG) pillars. Currently, ESG is employed to describe all the responsibilities of firms to their stakeholders, particularly, voluntary codes that exceed legislated requirements (Bassen, Kovacs 2008). The term ESG appeared in the United Nations' Principles of Responsible Investment. Since then the term has become very popular around the investment community and is mostly related to the responsible investment concept (sometimes, synonymously used with the term of socially responsible investment or sustainable investment) (Eccles, Viviers 2010). The ESG variable has been taken as a percentage of companies that discloses ESG data collected by Bloomberg out of total number of the listed securities for a country. In this context, it is assumed that environmental incentives, comprising various states' policy tools and voluntary activities, should lead to better environmental quality and competitiveness, at the same time.

In this dissertation it is assumed that the estimation of statistical significance of specific additional factors such as tax policy, the particular economic structure and R&D expenditure can explain the height of EKC. In addition, it is supposed that Europe as the leader in spreading ethical and social values in business may demonstrate a positive relationship of the number of the ESG enterprises. The empirical validation has two aims: to analyse the influence of GDP on GHG in order to test the EKC hypothesis and to test the chosen additional factors, which might impact the relationship between GHG and GDP in the EU region.

A general theoretical equation for estimating the considered economic relationship is given below.

$$Y_{it} = \alpha + \mu_i + \beta_1 X_{1t} + \ldots + \beta_k X_{kt} + \varepsilon_{it}, \tag{1}$$

where Y_{it} is a dependent variable for country i in time t;
X_{it} is an independent variable for country i in time t;
β_{it} denotes the regression coefficients;
μ_i is the cross–section specific effect;
ε_{it} is an error term.

The empirical investigation has two aims: to analyse the influence of GDP on GHG and to verify the chosen additional factors.

2.3. The Selection of Econometric Methods and Data

To validate the hypothesis the quantitative research analysis has been chosen. The econometric methods have been employed to understand whether the related values are of statistical significance and can prove the EKC hypothesis. This chapter aims to provide econometric methods for the research based on a modern econometric approach and the methods used by other researchers, as well as the particular features of the economic model built.

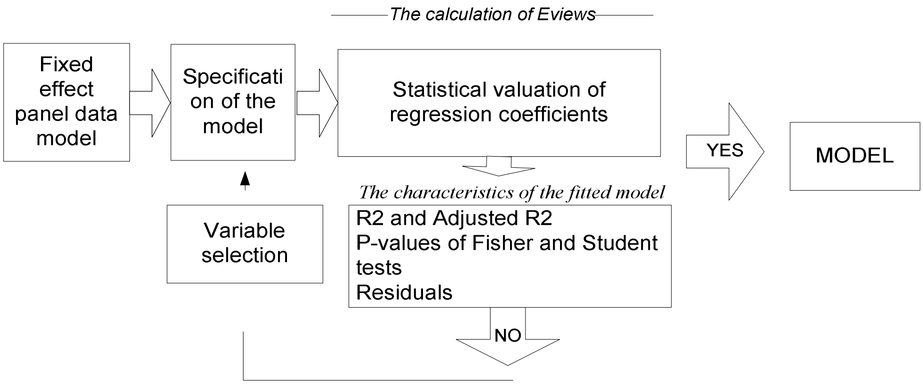


Fig. 4. Steps of the econometric estimation of the model
Source: made by author

The empirical study is based on the panel data, therefore, the econometric fixed effect panel data model is used for testing the hypothesis. This research covers the following econometric concepts:

- panel data;
- data normalisation;

- dummy variables;
- fixed effect panel data model.

The research area covers the history of state processes. To perform the analysis, the data on various countries over a certain time period are needed. In econometrics, this kind of the data structure is referred to as a panel data. A panel data set consists of a time series for each cross−sectional member in the data set.

In this research, the history of GHG, GDP, tax and other variables history for a chosen set of the countries, followed over a fifteen−year period is used. The example of the data structure is given below.

The chosen panel data contain the observations of the economic variables of European countries for 1995–2011.

When pooling data from different countries into a single model, it is important to refer to the differences in some variables. To have the comparable data, the data sets have been chosen for the analysis from Eurostat based on the same or very similar methodology. These data cover the EU countries. Only the countries with the complete data sets were chosen for the analysis to avoid possible data gaps. The data sets are associated with the same time periods for each cross section observation, and therefore are defined as a balanced panel. The data for this analysis are balanced data.

Table 5. The example structure of the analysed data

Country	Year	GHG	GDP	Tax	R&D	…
Lithuania	1995					
Lithuania	1991					
Lithuania	….					
Lithuania	2011					
Latvia	1995					
Latvia	1991					
Latvia	….					
Latvia	2011					
…..	1995					
……	……					
…….	2011					

Source: made by author

The analysis of the cubic model has one minor drawback because the estimated coefficients in front of the quadratic and cubic independent variables may be very small and need very high estimation precision, (down to 10−8, using the reported GDP per capita numbers). Possible solutions to this technical problem are as follows: a) to normalize the affected variables and to decrease the nominal number, or b) to use polynomial estimation of the equation coefficients. The first solution gives an additional advantage, allowing for graphical representation, comparability and interpretation of the results. In order to avoid potential distortions and/or very small beta coefficients, the data for GHG and GDP have been normalised to vary between 0 and 1, when the smallest value of the whole EU sample is equal to 0, and the largest value is equal to 1 (the formula is given below). At the same time, this facilitates the comparison of the results, as, for example, 0.5 is equal to the average EU level: the maximum and minimum values in the statistical analysis are not considered as very reliable because they are very sensitive to changes. However, the calculation of GDP and GHG is a complex, difficult and time−consuming method, therefore, these data series tend to be rather stable, and this kind of data normalization is suitable. The resulting data set allows us to compare relative positions of different countries in an overall sample, e.g. GDP expressed as 0.5 describes the country wealth as half of that of the most developed country. Similarly, GHG number of 0.5 indicates the country's environmental degradation, making half of that of the most contaminated country.

The formula is given below:

$$(GDP_{it} - \min GDP_{EU}) / (\max GDP_{EU} - \min GDP_{EU}) \qquad (2)$$

GDP_{it} is GDP for country i in time t;
$minGDP_{EU}$ is the minimum level of GDP for EU country;
$maxGDP_{EU}$ is the maximum level of GDP for EU country.

In the regression analysis, dummy numerical variables are used to distinguish specific characteristics. They help to justify unusual parameters in order to eliminate differences related to specific circumstances and to describe them in an equation.

According to Matyas, the simplest and most intuitive way to account for individual and/or time differences in behaviour, in the context of a panel data regression problem, is to assume that some of the regression coefficients are allowed to vary across individual and/or through time. The regression coefficients are unknown, but fixed parameters. When these are allowed to vary in one or two dimensions, we have a fixed effect model (Matyas 2008). To control for the country effects, many researchers estimated both fixed effects and random effects versions of the model (Selden, Song 1994; Panayotou 1997). A fixed effect is widely thought to be a more convincing tool for estimating ceteris paribus effect. It captures unobservable time − constant factors, which affect Y. All country− specific features (geographical location, climate zone, demographic features, etc.), which have not been included as explicit issues, are captured by the fixed effect (Wooldridge 2010). In order to eliminate the variation of the countries' GHG level, the intercept for each country is considered as a fixed effect.

Eviews was selected as the instrument of analysis. Eviews is a program for statistical and econometric analysis as well as forecasting. In order to validate the hypothesis, the chosen cubic model was tested, using the Eviews software. The software can estimate the cross−section weights, using a feasible GLS specification, assuming the presence of cross−section heteroskedasticity. GLS is used for estimating the variations in cross−section residuals. The fixed effects have been observed for the intercept specification, and cross-section weights for weighting. This implies that each pool will have an unrestricted intercept, and that each pool equation is weighted by an estimate of the cross−section residual standard deviation. In the panel data analysis, the term 'fixed effects estimator' (also known as the within estimator) is used to refer to an estimator for the coefficients in the regression model. If we assume fixed effects, we impose time independent effects for each entity that are possibly correlated with the regressor.

The model was validated by the characteristics of the fitted model:

- R^2 and Adjusted R^2.
- P−values of Fisher and Student tests.
- Residuals.

The parameters R^2 and adjusted R^2 have been chosen in the regression analysis as they help to estimate the explanatory power for curve fitting (Bogulauskas 2008). The higher the R^2 value (close to one), the better the explanatory power for the curve fitting. The closer R^2 is to 1, the greater the observed variation that can be explained by the fitted model. According to Devore and Berk, R^2 can be called the coefficient of determination, or the squared multiple correlation R^2 can be interpreted as the proportion of the observed variation that can be attributed to, or equivalently, explained by, the model relationship. Unfortunately, there is a potential problem with R^2: its value can be increased by including more coefficients in the model that are relatively unimportant. It is therefore desirable to adjust R^2 to take account of the fact that its value may be quite high just because many predictors were used relative to the amount of data. This the adjusted R^2 is smaller than the R^2 itself. The value of the adjusted R^2, much smaller than R^2, is a warning flag that the chosen model has too many predictors relative to the amount data (Devore, Berk 2011).

P−values of Fisher and Student tests. Specifically, the significance (P−value) was used to examine the statistical significance of the effect of the independent variables on the dependent variable to determine a critical value. Various researchers prefer different significance levels, depending on the particular application. There is no "correct" significance level. In this EKC estimation, P−value was used to determine the significance of GDP, GDP squared, GDP cubic and some additional factors. When the P−value is lower than 0.05, it indicates that this coefficient has a statistically significant explanatory power with the probability of 95%.

In the econometrics, the vertical distance of the actual observed Y from its predicted Y values is called a residual. It can be written as the difference between the actual value of Y and predicted value of Y (Residual = Actual value of Y – predicted value of Y). A particular method for studying the behaviour of residuals is the residual plot. The information about how well the regression assumptions are met by the particular regression model can be gleaned by examining the plots.

A single measure indicating the statistical properties of residuals is Durbin Watson statistics provided by Eviews (DW statistics being around 2 indicates that error terms are not serially correlated, while statistics closer to 0 or 4 indicates serial correlation).

To estimate the functional form of the relationship, one can look at the estimated values of β. Namely, if $\beta_1 > 0$ (respectively $\beta_1 < 0$) $\beta_2 = \beta_3 = 0$, then there is a monotonically increasing (decreasing) relationship between income and environment. If $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 = 0$, then, there is the inverted U−shaped relationship and turning point $t = - \beta_1 / 2\beta_2$. Finally, if $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 > 0$, then there is N−shaped relationship. If $\beta_1 = \beta_2 = \beta_3 = 0$, this indicates that there is no relationship between income and environment. Other cases are not presented in the EKC literature.

As mentioned above, to test the EKC hypothesis, the econometric model was used to evaluate the relationship between GHE and GDP. The income−environment relationship is often studied by specifying the function with quadratic and higher orders. The author of this work have chosen the reduced−form cubic equations (given in Chapter 3 below) to estimate the relationship between GHG and GDP. The selected model was taken as the most accurate and simple method, which can show the relationships among the considered elements. Other models, such as square and fourth and fifth degree models do not demonstrate the reliable relationships among the selected variables.

For the empirical validation, twenty two out of twenty eight European States sample were considered to determine the EKC relationship between GHG and GDP. Bulgaria, Romania and Croatia have not been included, because these countries joined the European Union only recently (in 2007 and 2013), and had too little time for the implementation of the European Union policy. Luxemburg, Cyprus, Malta have not been analysed either because their population is less than 1 mln., which may negatively impact calculations of per capita term. It was considered that the development path of these countries would be different from the whole sample.

The considered countries are presented in the table below and described by providing the information about their development stage. The information about the stage of development of each country presented in Table 6 is taken from the World Competitiveness Report (2011–2012).

Table 6. Stages of the countries' development according to the World Economic Forum

From efficiency−driven to innovation−driven	Innovation−driven
Estonia, Latvia, Lithuania, Poland, Slovakia	Belgium, Czech Republic, Denmark, Germany, Ireland, Greece, Spain, France, Italy, Hungary, Netherlands, Austria, Portugal, Slovenia, Finland, Sweden, United Kingdom.

Source: World Economic Forum. The Global Competitiveness Report 2011–2012

Different development levels of the countries analysed helped to extend the analysis, to include different stages of the country's development, and, in addition, the hypothesis about a similar pattern of the EKC curve in the countries found at the same development stage was tested.

Hence, relying on the use of economic logic and the most suitable statistical information, two hypotheses have been raised. The EKC hypothesis was derived from a simple model of the economy, in other words, the unidirectional causality from the economy to the environment was assumed. The presented technique of of the evaluation of the impact of economic growth on the environmental quality indicators (GHG variable is chosen) (Table 7).

Table 7. The technique of the evaluation of the impact of economic growth on the environmental quality indicators (GHG variable is chosen).

Stage	The steps of the analysis	Applied methods and models
Hypothesis 1: EKC, reflecting the relationship between emissions and GDP, changes its position and shape, depending on the level of country's economic development.		
1. To evaluate the impact of GDP on the indicators of environmental degradation	1.1. The reduced form EKC estimation for individual countries	Data normalization $(GDP_{it} - \min GDP_{EU})/(\max GDP_{EU} - \min GDP_{EU})$ Multiple regression: $GHG_{it} = \alpha + \mu_i + \beta_{1i}GDP_{it} + \beta_{2i}GDP_{it}^2 + \beta_{3i}GDP_{it}^3 + \varepsilon_{it}$
	1.2. The reduced form EKC estimation by the fixed effect panel model for the region	The fixed affect panel data model: $GHG_{it} = \alpha + \mu_i + \beta_1 GDP_{it} + \beta_2 GDP_{it}^2 + \beta_3 GDP_{it}^3 + \varepsilon_{it}$
Hypothesis 2: additional exogenous variables have substantial impact on the form of the EKC.		
2. To evaluate the impact of exogenous factors	2.1. To estimate the impact of exogenous factors	The extended fixed affect panel data model: $GHG_{it} = \alpha + \mu_i + \beta_1 GDP_{it} + \beta_2 GDP_{it}^2 + \beta_3 SECT_{it} + \beta_4 RD_{it} + \beta_5 TAX_{it} + \beta_6 ENERTAX_{it} + \beta_7 ESGCORP_{it} + \beta_8 CRIS08_{it} + \beta_9 CRIS_{it} + \varepsilon_{it}$
3. To create scenarios using the specified model (5)		
GHG_{it} is a dependent variable for country i in time t; *GDP_{it} is an independent variable for country i in time t;* *$SECT_{it}$ is an independent variable for country i in time t;* *RD_{it} is an independent variable for country i in time t;* *TAX_{it} is an independent variable for country i in time t;* *$ENERTAX_{it}$ is an independent variable for country i in time t;* *$ESGCORP_{it}$ is an independent variable for country i in time t;* *Cris08 is a dummy variable for country i in 2008 in time t;* *Cris is a dummy variable for country i in 2009−2011 in time t;* *β denotes the regression coefficients;* *μ_i is the cross−section specific effect;* *ε_{it} is an error term*		

Source: made by author

In this work, the technique has been created to analyse the relationship between economic growth and the environmental indicators in order to have the instrument, which could help to estimate the EKC height. The technique for evaluating the impact of economic growth on the indicators of environmental degradation allows to create the final model with the aim to reduce the height of EKC. In the dissertation the variable of GHG is chosen as the dependable variable for creation of the final model. Based on the analysed theoretical literature and econometric issues, two models have been chosen for estimation the impact of economic growth on the indicators of environmental degradation. These are the standard cubic equation with GDP per capita as an explanatory variable and the model with additional factors. The reduced EKC should be tested twice: the model for individual countries and for the whole sample. The EKC for the separate countries have to be tested in order to group the considered countries, based on their EKC patterns. Taking into account the above mentioned theoretical arguments, and since the research focus has been to examine the scale of activities and since the structure of economy and policy affects the income–environment relationship, the expanded model includes some additional factors based on the economic logic and data availability. GHG, chosen as a dependable variable, was valued as an independent variable similar to other indicators.

2.4. Conclusions to Chapter 2

1. The issues related to the climate change are among the highest priorities of the international environmental policy. The European Union is the leading region tackling this problem. The reduction of GHG by 20 percent is explicitly introduced in European strategy 2020, and further reduction by 80 is included in the European Union political guideless. According to the presented data, the main source of GHG is related to energy consumption, while high divergence in GHG amounts remains even among separate EU countries. Therefore, GHG is a policy target, and many countries consider this variable to be a potentially interesting research object reflecting the environmental characteristics.
2. The reduced form EKC approach has been used as a tool showing how economic growth affects the environment. The extended analysis captures different types of effects that economic growth has on GHG. These are the scale of economic activity, the structure of economy, technological development, economic and fiscal instruments, and voluntary activities in business. The study is based on a simple model of per capita economy, where there is no feedback from the environment to

economy, meaning that unidirectional causality from the economic development to the GHG level has been assumed.

3. In order to estimate the effects of economic growth in the European Union, the GDP, the share of a particular polluting industry, R&D, environmental taxes, energy taxes and percentage of companies that discloses ESG were used as proxy variables. GDP and GHG data are taken in per capita terms in order to avoid the countries' differences. GDP per capita and economic structure are the main economic variables impacting the GHG level. The indicators 'Research and experimental development business expenditure' indicates the determined business action to concentrate technological innovation on reducing human beings' pressures on the environment. Taxes variable was chosen as a potential policy options for negative externalities. Percentage of companies that discloses ESG were used as a proxy variable is chosen in order to test the instruments of the market mechanism as working on behalf of the environment.
4. For the present analysis, twenty two states from twenty eight European States sample have been chosen as a balanced panel data sample to empirically validate the presented technique. For the models, the multiple regressions with dummy variables have been used for single state models to make the estimation, and a fixed effect panel data model has been used for the final sample estimation. Eviews was selected as the instrument of analysis because the software can estimate cross−section weights using a feasible GLS specification, assuming the presence of cross−section heteroskedasticity. The model was validated based on the characteristics of the fitted model: R^2 and Adjusted R^2, P−values of Fisher and Student's tests and residuals.

3

The Empirical Testing of the Impact of Economic Growth on Greenhouse Gas Emissions

In this chapter, the empirical check of the validity of the EKC relationship for European countries is performed based on the proposed tecnique. The analysis is based on the data of twenty two member−states of the European Union in the period of 1995–2011. The data is taken from the Eurostat database. The aim of this chapter is the empirical evaluation of the relationship between GHG as the main variable of climate change and GDP based on the EKC approach to the analysis of the selected European countries for the period of 1995–2011. The chapter has the following structure: In section 1, the reduced form of the EKC for separate countries is evaluated in order to empirically test the validity of the EKC relationship for individual European countries. The estimation analyses the specific relationship patterns in some of the selected countries, based on the level of a countries' development, to gain the insights into the environmental trends and similarities between individual countries in order to identify their basic common features. In Section 2, the reduced form of the EKC estimate by the fixed effect panel model for the whole sample is presented. In Section 3, the impact of the selected additional variables (the share of a particular polluting industry, R&D, environmental taxes, energy taxes and percentage of companies that discloses ESG) are empirically tested, using the expanded form of the EKC estimate in order to find the best tools for reducing the EKC height. In Conclusions, summarized results and the concluding remarks are provided and possible areas of further research are defined.

The results of this chapter were published in four articles and a presentation was made in the 54th International Scientific Conference in Riga Technical University. The results presented in the chapter can be found in the published articles of the author (Lapinskienė *et al.* 2014; 2013; Lapinskienė, Radavičius 2014; Lapinskienė, Tvaronavičienė 2012).

3.1. The Reduced form Environmental Kuznets Curve Estimates for Individual Countries

The aim of this chapter is the evaluation of the relationship between GHG and GDP in chosen individual European countries for the period of 1995–2011. At first stage of the empirical analysis, twenty two member states of the European Union were considered to determine if each of them has a statistically significant relationship between GHG and GDP, and to verify the reduced EKC (Table 7). The data for the selected sample is available in the Eurostat database for the period of 1995–2011 (Annex A). The initial analysis confirmed that the international financial crisis (started at the end of 2008), could impact the results of the analysis, particularly, in the countries, where economic growth rate was most volatile. The comparison of the complete time period (1995–2011) with the shortened time period (1995–2008) proved that the analysis of the later shows much better statistical results. In this section, the multiple regression is chosen as the statistical method to verify the Hypothesis 1. The reduced−form cubic equations given below as a standard instrument for estimating the relationship between GHG and GDP have been chosen. The selected model was taken as the most accurate and simple method, which can show the relationships among the considered elements. Other models, such as fourth and fifth degree models do not demonstrate the reliable relationships among the selected variables. A general formula (3) was used to estimate the relationship for every single country.

$$GHG_{it} = \alpha + \mu_i + \beta_{1i} GDP_{it} + \beta_{2i} GDP_{it}^{\;2} + \beta_{3i} GDP_{it}^{\;3} + \varepsilon_{it}\ , \quad (3)$$

where GHG_{it} is a dependent variable for country i in time t;
GDP_{it} is an independent variable for country i in time t;
β_{it} denotes the regression coefficients;
μ_i is the cross−section specific effect;
ε_{it} is an error term.

The models were calculated based on the particular country's data. An example of the initial data for Lithuania and the respective values calculated by Eviews are given in Annex B. The regression coefficients and the parameters of model validation of the reduced cubic functional form calculation for each given country are presented in Table 8 given below.

Table 8. Regression parameter estimates for the period 1995–2008

Sample		Model coefficients				The parameters of model validation	
No	Country	NNGDP2	NNGDP2^2	NNGDP2^3	α	Adjusted R^2	P−value of Fisher test
1	Lithuania	−1.2903	13.5263	−30.9782	0.1110	0.7322	0.0009
2	Latvia	−1.7651	20.8158	−65.0492	0.0557	0.7743	0.0004
3	Estonia	−2.4129	17.2699	−28.8144	0.4616	0.4017	0.0438
4	Denmark	11.4737	−41.7957	45.8986	−0.5128	0.6633	0.0028
5	Belgium	−19.4781	65.8025	−74.7328	2.3558	0.9097	0.0000
6	France	5.1015	−17.0846	17.3119	−0.2630	0.9487	0.0000
7	Netherlands	1.8602	−7.3916	7.6740	0.3002	0.9336	0.0000
8	Germany	−9.7583	27.8003	−27.1996	1.5032	0.9459	0.0000
9	Sweden	−3.2933	9.6510	−10.1712	0.5493	0.8633	0.0000
10	United Kingdom	−0.5604	0.3900	−0.2453	0.4374	0.8681	0.0000
11	Austria	−25.4198	80.7301	−83.2776	2.8577	0.5609	0.0101
12	Finland	−10.6022	39.2684	−46.6388	1.3367	−0.1620	0.7589
13	Greece	4.1537	−14.0617	15.2369	−0.0799	0.8948	0.0000
14	Spain	−1.1780	11.7493	−22.5859	0.1386	0.8597	0.0000
15	Italy	−19.6026	77.6957	−100.2987	1.8288	0.8538	0.0000
16	Portugal	−3.4542	32.9273	−82.1116	0.2003	0.7838	0.0003
17	Ireland	4.5267	−11.4633	8.5009	0.0123	0.7095	0.0014
18	Hungary	−2.6123	25.2928	−76.6862	0.2326	0.6027	0.0062
19	Poland	−4.4331	32.0398	−65.7884	0.4307	0.6467	0.0035
20	Slovenia	0.9315	−4.6318	9.1950	0.1590	0.7631	0.0005
21	Slovakia	−1.1871	8.2232	−20.5070	0.2768	0.5927	0.0070

22	Czech Republic	−8.9224	47.4409	−81.7946	0.9533	−0.0428	0.5109

Source: made by author

The results of the econometric analysis are discussed based on steps of econometric estimation of the model in Chapter 2. In this step, the residuals of every country have not been evaluated as the number of observations is not large enough. The study of the residual plot will be presented based on the final model of the whole sample. The results of the statistical analysis for individual countries, presented in the table above, revealed that, in most cases, the relationship between GHG and GDP was quite strong. The selected model showed a low explanatory power for only two countries (Finland and Czech Republic), where the values of R^2 were small and P−value was substantially larger than 0.05 (see Table 8).

The remaining countries have been unified into five groups. The subdivision was based on the geographical region of the countries and the level of their development (in this case referred to as GDP per capita). The groups with the supplemented columns are presented in the table below.

Table 9. Country groups based on the relationship between economic growth and greenhouse gas emissions

Country groups	States	Min GDP/per capita	Max GDP/per capita	Difference
The Baltic region	Lithuania	5.200	16.600	11.400
	Latvia	4.600	14.700	10.100
	Estonia	5.300	17.500	12.200
Western Europe	Belgium	18.900	29.900	11.000
	Denmark	19.300	31.500	12.200
	Austria	19.700	32.400	12.700
	France	17.000	27.300	10.300
	Germany	18.900	30.500	11.600
	Sweden	18.300	31.700	13.400
	UK	16.900	29.500	12.600
	Netherlands	18.100	33.600	15.500
Southern Europe	Italy	17.800	26.100	8.300
	Portugal	11.300	19.700	8.400
	Greece	12.300	23.100	10.800
	Spain	13.400	26.200	12.800

Central – Eastern Europe	Slovakia	7.000	18.500	11.500
	Slovenia	10.900	22.700	11.800
	Poland	6.300	16.200	9.900
	Hungary	7.500	16.500	9.000
High growth	Ireland	15.200	36.500	21.300

Source: made by author

When comparing the minimum and the maximum levels of GDP per capita during the period of 1995–2011, several features can be observed. The lowest level refers to 1995 and the highest, depending on a country, varies in the period 2007 to 2011. During the selected period, the states demonstrate a stable growth from 1995 to 2008. Then in 2009, the growth slowed down due to the financial crisis and recovered somewhere in 2010 and 2011. The Baltic States which joined the Union in May 2005 started from approximately 5000 GDP/capita PPS and, finally reached 16000 GDP/capita PPS. At the same time, Western countries like Belgium, Denmark, Austria, France, Germany, Sweden, UK, Netherlands, Italy and Ireland started from approximately 18000 GDP/capita PPS in 1995 and reached approximately 30000 GDP/capita PPS in 2011. The countries located in the Southern part of Europe, such as Portugal, Greece and Spain started from approximately 12000 GDP/capita PPS and reached approximately 20000 GDP/capita PPS. The states of Central – Eastern Europe, such as Slovakia, Slovenia, Poland and Hungary, demonstrate the growth similar to the Baltic region, varying from around 7000 to 18000, as these countries united historical legacy. Ireland as a high growth country, demonstrated very high growth during this period (growing from 15200 to 36500).

To clarify the results of multiple regression, graphical representations were used. Hence, the curves of the countries, based on their geographical location and development similarities, are presented in the separate charts. Twenty countries were divided into five groups. A visual inspection of individual charts showed different relationship patterns for different states, depending on their development stage. The charts are given below (Figures 5–8).

The comparison of the height of the EKC curve and its form is complicated, however, a general pattern (a functional form of the curves) can be identified. The data are normalised based on the equation given in Chapter 2. The axis X presents the normalised data of the GHG level, the axis Y refers to the level of the normalised data of the GDP in PPS. Every point captures the GHG and GDP level for a particular year.

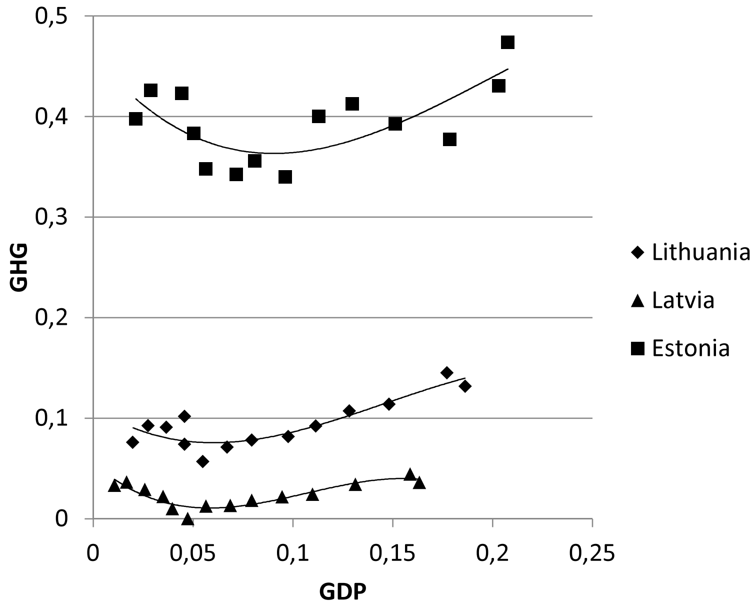


Fig. 5. The relationship between GHG and GDP in the Baltic states
Source: author's calculations

The curve for Estonia is at the top as the level of GHG is the highest in this country. The main feature of the EKC pattern of the countries of this group is as follows: at the beginning, it goes downward – the GHG decreases until the turning point is reached and, then, goes upwards with the GDP growth. The considered countries have different bottom turning points. After reaching turning points further GDP growth should result in the decrease of GHG. According to WEF, these states are in transition from the efficiency−driven to innovation−driven stage.

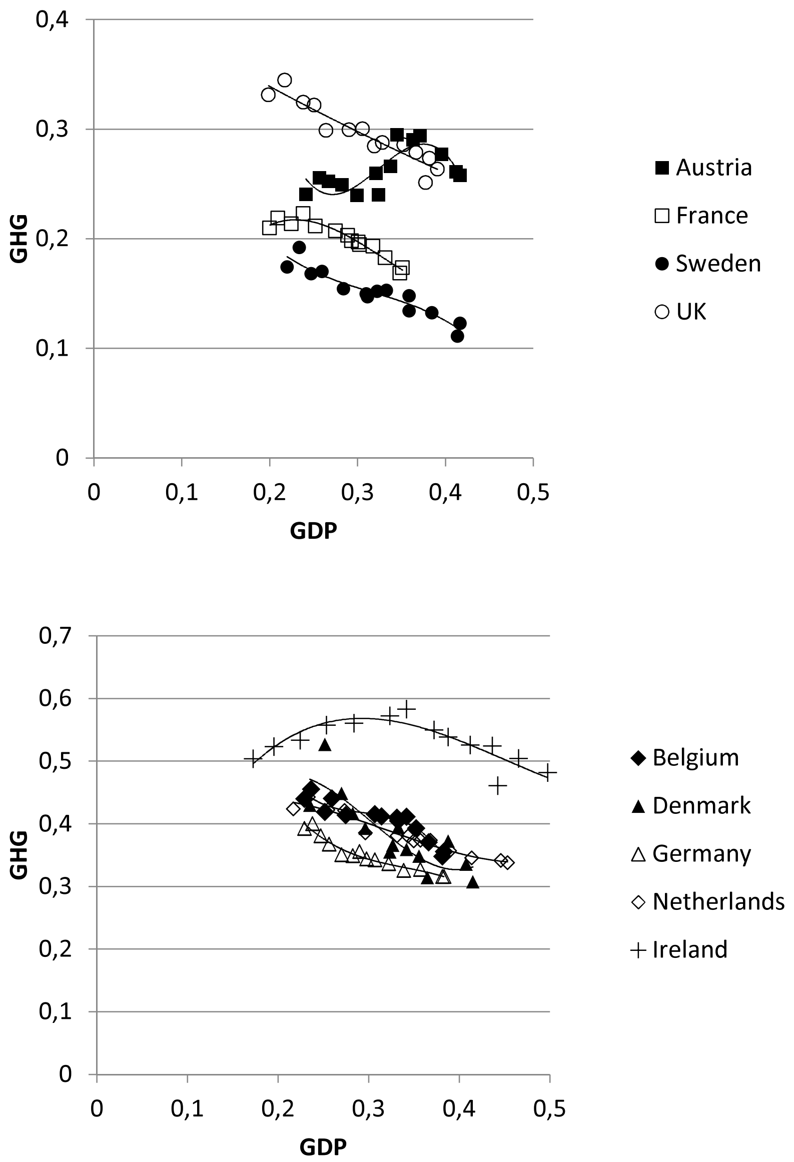


Fig. 6. The relationship between GHG and GDP in Western European countries and Ireland. *Source*: author's calculations

The group of the developed countries (Belgium, Denmark, Austria, France, Germany, Sweden, UK and Netherlands) has been split into two charts in order to have a clear view. The trends of Austria, France, Sweden and UK are presented in the first part. In France, the turning point is approximately at 0.25 normalised GDP per capita in PPS, then, after reaching it, the curve goes down. The second chart includes Belgium, Denmark, Germany, Netherlands and Ireland. The trends of Belgium, Denmark, Germany, Netherlands, Austria, Sweden and UK shows the GHG decrease, while GDP per capita increases. In the chosen period, the developed countries demonstrated the last part of the EKC, when GHG was decreasing, while GDP per capita was increasing. The trend of Ireland is the most interesting one as it demonstrates the whole EKC from 1995 to 2011. At the beginning of this period, Ireland had 15200 GPD/capita in PPS, while at the end, it reached 36500 GPD/capita in PPS. During the analysed period the country has demonstrated a very high growth and the path of development has captured the whole EKC. However, the tail of trends in Germany, Netherland and Denmark shows that a positive effect of growth on GHG may change.

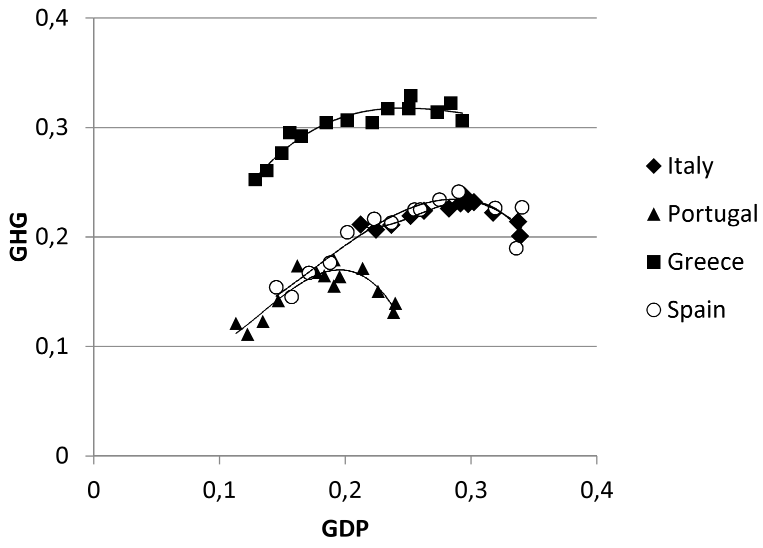


Fig. 7. The relationship between GHG and GDP in Greece, Spain, Italy and Portugal.
Source: author's calculations

The relationship between GHG and GDP in Greece, Spain, Italy and Portugal demonstrates the top part of the inverted U−shaped relationship, where the GHG level increases within the increase in GDP and, then, after reaching the turning point, the curve goes down within the GDP increase. The top turning points are different, demonstrating approximately at 0,27 normalised GDP/capita in PPS in Greece, 0,3 in Spain and Italy, 0,2 in Portugal. The trends of these countries clearly shows a similar development path of the states of Southern Europe.

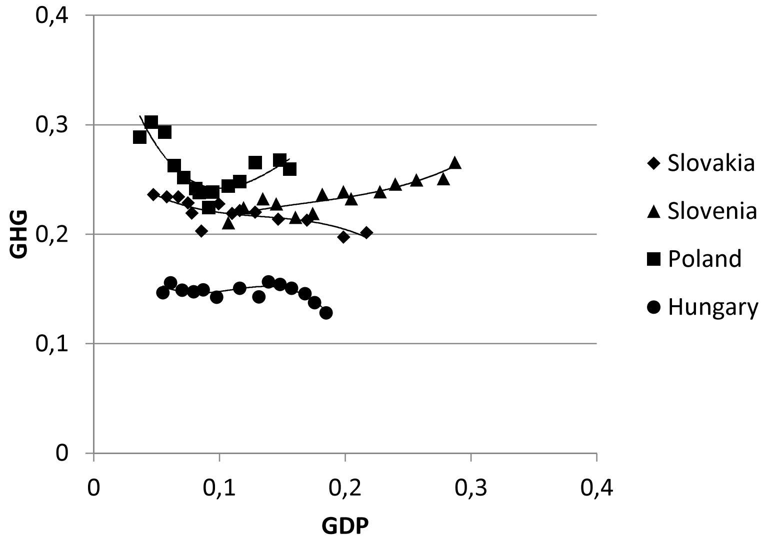


Fig. 8. The relationship between GHG and GDP in Slovenia, Slovakia, Czech Republic and Poland. *Source*: author's calculations

In this chart, four curves demonstrate the relationship between GHG and GDP in Slovenia, Slovakia, Czech Republic and Poland. This group represents the most diverging patterns. The curve representing Poland is at the top of the chart because the GHG level is rather high in this country. At the beginning, the curve of Poland decreases with the increase of GDP and then, reaching the bottom point approximately at 0.1 normalised GDP/capita in PPS, starts increasing. It seems that it is the beginning of a new EKC. Slovenia demonstrates the first rather flat part of the EKC. The trends of Slovakia and Hungary showed the increase of GHG level with the increase of GDP.

It can be observed that the position of the function of any particular country depends its development stage. The visual sight of the whole sample demonstrates that the full EKC can be built based on the data for all countries. It begins with is the Baltic states and Central and Eastern Europe, then come

Southern European countries, followed by the developed Western European countries with some tendencies of starting a new EKC. The countries belonging to the Central and Eastern European and the Baltic States have some similarities in their history. These countries demonstrate small different trends in economic growth, but the patterns of the EKC curves are similar, showing the GHG increase with GDP increase. The curves for the states of Southern Europe refer to the middle part of the EKC. The countries of Western Europe demonstrate the last part of EKC, where GHG level decreases with the increase of GDP. These tendencies may indicate that after some time the analysed countries would follow general EKC form, but some specific geographic or economic features could still impact the differences.

It can be seen that, in general, the research confirmed the presence of the inverse U–shaped relationship, indicating that, at a particular level of GDP and economic growth, the pollution increases, but after reaching some threshold, the trend reverses so that, at a higher development stage, further economic growth leads to the improvement of the environment. Turning points are different in particular countries. In the developed countries, the trend shows, that when countries reaches a very high development level, as seen in Germany, Netherlands and Denmark, further GDP growth may increase GHG.

The findings of the research highlight several areas for further investigation. Firstly, the analysis of the specific factors, may be important for developing and pursuing the environmental policy. Secondly, further research is needed to determine why a stable causal relationship between GDP and GHG could not be observed during the crisis.

The research highlighted a specific relation between the economic growth and environmental trends in every chosen country based on their geographical location and development level. Hence, according to the results of this chapter the main task of further research should be the evaluation of the reduced form EKC, using the fixed effect panel model for the whole sample.

3.2. The Reduced form Environmental Kuznets Curve Estimation by the Fixed Effect Panel Model for the Whole Sample

The aim of this chapter is the evaluation of the relationship between GHG and GDP based on the EKC approach in twenty European countries for the period 1995–2011. The selected countries comprise Lithuania, Latvia, Estonia, Belgium, Denmark, Austria, France, Germany, Sweden, UK, Netherlands, Italy, Portugal, Greece, Spain, Slovakia, Slovenia, Poland, Hungary and Ireland. The data on these countries for the period 1995–2011 were pooled together to estimate the reduced EKC for the whole sample. The total pool balanced observations cover 340 points, consisting of the data for 17 years 20 countries. For the panel model estimation, the Eviews software was used as an instrument to estimate the pooled EGLS (cross−section weight) method. The data were normalised based on the equation given in Chapter 2. The selected theoretical model is given below:

$$GHG_{it} = \alpha + \mu_i + \beta_1 GDP_{it} + \beta_2 GDP_{it}^{2} + \varepsilon_{it} \qquad (4)$$

where GHG_{it} is a dependent variable for country i in time t ;
GDP_{it} is an independent variable for country i in time t;
β_{it} denotes the regression coefficients;
μ_i is the cross−section specific effect;
ε_{it} is an error term

The main results of the econometric estimation are presented in Table 10 and analysed in the remaining part of the section.

Table 10. The results of the reduced model estimation

Dependent Variable: NNGGE_?
Method: Pooled EGLS (Cross-section weights)
Date: 02/11/14 Time: 15:10
Sample: 1995 2011
Included observations: 17
Cross-sections included: 20
Total pool (balanced) observations: 340
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.255256	0.007155	35.67535	0.0000
NNGDP2_?	0.317121	0.055202	5.744778	0.0000
NNGDP2_?^2	-1.134639	0.101911	-11.13366	0.0000
Fixed Effects (Cross)				
LITHUANIA--C	-0.178171			
LATVIA--C	-0.244088			
ESTONIA--C	0.124461			
GREECE--C	0.025695			
SPAIN--C	-0.065334			
ITALY--C	-0.039527			
PORTUGAL--C	-0.130695			
DENMARK--C	0.135919			
BELGIUM--C	0.152293			
FRANCE--C	-0.057982			

GERMANY--C	0.100652
NETHERLANDS--C	0.153390
AUSTRIA--C	0.032017
SWEDEN--C	-0.088904
UK--C	0.041846
IRELAND--C	0.289948
POLAND--C	-0.016136
SLOVENIA--C	-0.036886
SLOVAKIA--C	-0.062749
HUNGARY--C	-0.135747

Effects Specification

Cross-section fixed (dummy variables)

Weighted Statistics

R-squared	0.968269	Mean dependent var	0.301344
Adjusted R-squared	0.966173	S.D. dependent var	0.170553
S.E. of regression	0.030296	Sum squared resid	0.291873
F-statistic	462.0801	Durbin-Watson stat	0.736245
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.939717	Mean dependent var	0.251643
Sum squared resid	0.294939	Durbin-Watson stat	0.618411

Source: authors calculations in Eviews

The reduced form EKC was estimated, using both cubic and quadratic functions, but cubic estimation coefficient did not show a strong statistical significance (See Annex C). It can be explained by the data plot (using MS Excel), where quadratic and cubic estimations give very similar functional forms. The axis X presents the normalised data of the GHG level, the axis Y refers to the level of normalised data of the GDP in PPS. Every point captures the GHG and GDP level for a particular year. In this analysis, the reduced form EKC estimation was assessed for the whole sample.

The analysis of the estimated model coefficients proved the existence of the EKC form. Emissions can be said to exhibit a meaningful Kuznets relationship with per capita GDP if $\beta_1 > 0$, $\beta_2 < 0$, – and if the turning point, $-\beta_1 / 2\beta_2$, is a "reasonably" low number (Selden, Song 1994). The calculation shows that the turning point is around 0.14 the normalized GDP/per capita (-0.317121 / 2x (-1.134639)) = 0.1397744). The visual results have confirmed the presence of the inverse U-shaped relationship in the chosen sample, indicating that, at a particular level of GDP and economic growth, the pollution increases, but after reaching some threshold, the trend reverses. The trends of these countries clearly demonstrate the development path in Europe.

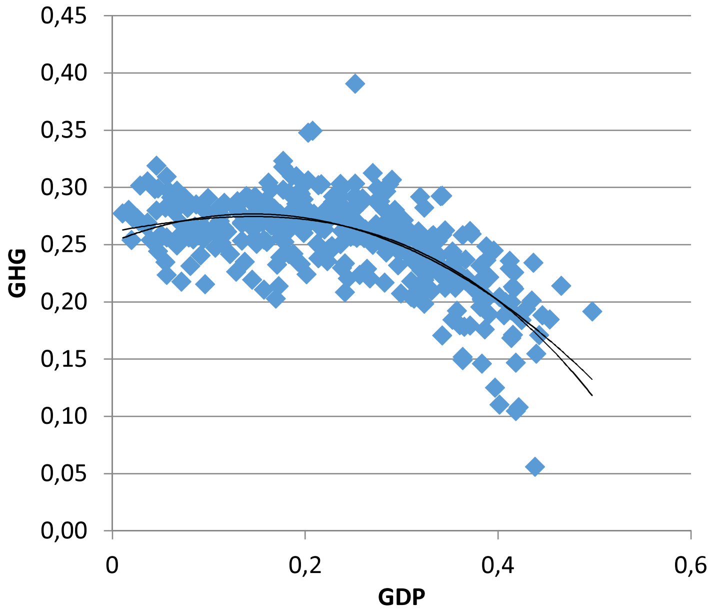


Fig. 9. Comparison of the cubic and quadratic function models for the whole sample
Source: calculated by author

The model was validated by the characteristics of the fitted model (see Fig. 4). R^2 and Adjusted R^2 have been calculated by Eviews (Table 10). R-squared is 0.968269 and Adjusted R-squared is 0.966173. R-squared is very high due to its specific estimation for the pooled data series as noted in Chapter 2.

Specifically, the P–value of Student's test was used to examine the statistical significance of the effect of the independent variables on the dependent variable. In this EKC estimation, P–value was used to determine the significance of GDP, GDP squared and GDP cubic. When P–value is lower than 0.05, it indicates that this coefficient has a statistically significant explanatory power with the probability of 95% (it is provided in column "Prob" in Table 10).

The *F–statistic* is used to test the overall fit of the model or, more specifically, if all of the slope coefficients in the regression model are zero. As shown in the table, F–statistics of the final quadratic model is 462.0801, while probability of zero F–statistics is non-existent. Similar results are given by the cubic model estimate is 432.4162 and probability of zero F-statistics is non–existent (Annex C).

The plot analysis of residuals presented in Annex E has been chosen as the method to study the behaviour of residuals. The information about how well the regression assumptions are met by the particular regression model can be seen from the plots. The residual plots are provided for every analysed country in the chart. A measure indicating the statistical properties of residuals is Durbin Watson statistics provided by Eviews. In this case, Durbin–Watson statistic is 0.736245, indicating substantial serial correlation of the residuals. Graphical analysis of the residual plots also gives similar results, clearly indicating similar patterns in the groups of the countries as presented in Chapter 3.1., specifically, for the Baltic States (Lithuania, Latvia and Estonia) and South European countries. Western countries except for Austria also exhibit the recurring residual patterns (Annex E). In this chapter, further analysis of residuals has not been performed because a more substantial analysis is provided of the residuals remaining in the estimation of the extended EKC model.

The summarised results of the fixed effect panel model confirm the presence of the inverse U–shaped relationship in the chosen European countries, indicating that, at a particular level of GDP and economic growth, the pollution increases, but after reaching some threshold, the trend reverses so that, at a higher development stage, further economic growth leads to the improvement of the environment. For further investigation, it will be interesting to extend the research area by including other countries which are at various stages of development.

Further research should be aimed at extending the reduced EKC model by including additional indicators, which might impact the relationship between GHG and GDP The analysis of this kind might be useful for developing the environmental policy in order to find the tools for reducing the height of the EKC.

3.3. The Extended Fixed Effect Panel Data Model

The aim of this chapter is the evaluation of additional factors, which might impact the relationship between GHG and GDP based on the EKC approach in the whole sample for the period 1995–2011. The variables, such as the share of a particular polluting industry, R&D, environmental taxes, energy taxes and percentage of companies that discloses ESG were included in the model. The variables have been chosen based on the economic model (Chapters 2.2.) and the available statistical data. This section presents the part of the research, where the Hypothesis 2 has been empirically tested. The extended EKC analysis helps to verify if the selected variables have a statistically significant impact on the EKC relationship. At the same time, the additional factors should explain at least some of a country's intercept differences observed in the reduced model.

At this stage of analysis, the period 1995–2011 has been estimated. At the same time, two additional dummy variables were added to the model ("Cris08" and "Cris") to test if crisis had any potential impact on the EKC relationship and its significance. "Cris08" consists of dummy variables, which are equal to zero for the whole period, except for those equal to one for 2008. This helps to estimate the crisis shock for GDP and GHG relationships in the first year of the crisis (2008). The dummy variable "Cris" estimates the potential impact for the remaining years of the crisis. The examples of dummy variables are given in Annex D. The proxy variables, which are included into the model, are presented in the table given below.

Table 11. The expected sign of modelled factors

Short name	Proxy variables	Description of proxy variable	Expected sign
SECT	The share of a particular polluting industry	Agriculture+Industry+Construction value added as percentage of total GDP	Positive
RD	R&D	Research and experimental development include all expenditures within the enterprise business sector on the national territory during a given period and is shown as a percentage of GDP	Negative
TAX1	Environmental taxes	As percent of the total taxes and social contributions	Negative
ENERGTAX	Energy taxes	Ratio of energy tax revenues to final energy consumption ((Euro per tonne)	Negative
ESGCORP	ESG score	Percentage of companies that discloses ESG data collected by Bloomberg out of total number of the listed securities for a country	Negative

Source: made by author

The large share of a particular polluting industry might cause higher level of GHG and it is expected to obtain a positive mathematical sign in the model. This measure is represented as a percentage of value added of the Agriculture+ Industry+ Construction sectors in total GDP.

In the sustainable development, it is assumed that the largest part of R&D expenditure in theory might be related to the environmental friendly solutions. On the other hand, chosen model estimates various countries representing different starting points of R&D expenditure and the results might not be obvious. It should be noted that real investments in R&D may show a substantial lag between the investment time and a positive result, while the statistical impact might not be caught from the past data. Despite these doubts, it is expected to have a negative sign of the coefficient by R&D.

Measures representing the environmental policy options are reflected by energy and environmental taxes. Taxes represent a classical and potentially reliable instrument of the environmental policy, used for reducing the harm of human activities on the environment. This research does not go deeper in the discussion about the effectiveness of these instruments. It is assumed that higher taxes might reduce the level of GHG and it is expected to have negative signs of coefficients representing taxes.

The impact of business ethics on the development of human beings is a topic of various philosophic and economic discussions. In our days, when degradation of the environment is huge, the environment cannot not be described as luxury goods any more, but should be treated as inherent characteristic of humans' development. The authors believe that, in the future working in line with the environmental principles could be the essential part of economics. In this research, it is generally assumed that sustainable enterprises might help to lower the level of GHG and it is expected to have negative sign in estimation of the variable 'ESG score'. It is a modest attempt to empirically estimate the ethical contribution of business to economic development.

In order to test the statistical significance of these variables, the reduced equation has been expanded. The selected theoretical model for this step of the research is given below:

$$GHG_{it} = \alpha + \mu_i + \beta_1 GDP_{it} + \beta_2 GDP_{it}^2 + \beta_3 SECT_{it} + \beta_4 RD_{it} + \beta_5 TAX_{it} + \beta_6 ENERTAX_{it} + \beta_7 ESGCORP_{it} + \beta_8 CRIS08_{it} + \beta_9 CRIS_{it} + \varepsilon_{it} \quad (5)$$

GHG_{it} is a dependent variable for country i in time t;
GDP_{it} is an independent variable for country i in time t;
$SECT_{it}$ is an independent variable for country i in time t;
RD_{it} is an independent variable for country i in time t;
TAX_{it} is an independent variable for country i in time t;
$ENERTAX_{it}$ is an independent variable for country i in time t;
$ESGCORP_{it}$ is an independent variable for country i in time t;
$Cris08_i$ is a dummy variable for country i in 2008 in time t;
$Cris_{it}$ is a dummy variable for country i in 2009–2011 in time t;
β denotes the regression coefficients;
μ_i is the cross–section specific effect;
ε_{it} is an error term

The extended model has nine indicators which can decrease the reliability of the model. Despite this, the parameters of the model are in agreement with the theoretical econometric methodology.

In the first part of the work the variable ESGCORP has not been included because its values were not available for the whole tested period. This variable will be included in later estimations of the model covering only the data for 2007–2011 period. The results of, the statistical analysis covering the whole period are presented in Table 12 and explained below.

Table 12. Regression parameter estimates for the extended model

Dependent Variable: NNGGE_?
Method: Pooled EGLS (Cross-section weights)
Date: 02/11/14 Time: 15:07
Sample: 1995 2011
Included observations: 17
Cross-sections included: 20
Total pool (balanced) observations: 340
Linear estimation after one-step weighting matrix
White cross-section standard errors & covariance (no d.f. correction)
WARNING: estimated coefficient covariance matrix is of reduced rank

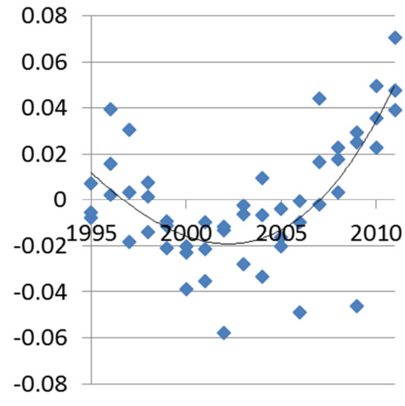
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.020855	0.034682	0.601318	0.5481
NNGDP2_?	0.676672	0.054368	12.44615	0.0000
NNGDP2_?^2	-1.231759	0.080703	-15.26284	0.0000
RD_?	5.37E-05	1.98E-05	2.710237	0.0071
TAX1_?	0.016585	0.004007	4.139092	0.0000
ENERGTAX_?	-0.000650	7.92E-05	-8.216235	0.0000
SECT_?	0.006655	0.000660	10.08989	0.0000
CRIS08	-0.014409	0.002080	-6.927038	0.0000
CRIS	-0.030796	0.003327	-9.256045	0.0000
Fixed Effects (Cross)				
LITHUANIA--C	-0.177555			
LATVIA--C	-0.198776			
ESTONIA--C	0.123422			
GREECE--C	0.098777			
SPAIN--C	-0.060800			
ITALY--C	0.011196			
PORTUGAL--C	-0.090001			
DENMARK--C	0.169786			
BELGIUM--C	0.121905			
FRANCE--C	-0.015361			
GERMANY--C	0.085391			
NETHERLANDS--C	0.125808			
AUSTRIA--C	-0.021184			

SWEDEN--C	-0.109429
UK--C	0.102879
IRELAND--C	0.201031
POLAND--C	-0.020398
SLOVENIA--C	-0.078597
SLOVAKIA--C	-0.118981
HUNGARY--C	-0.149114

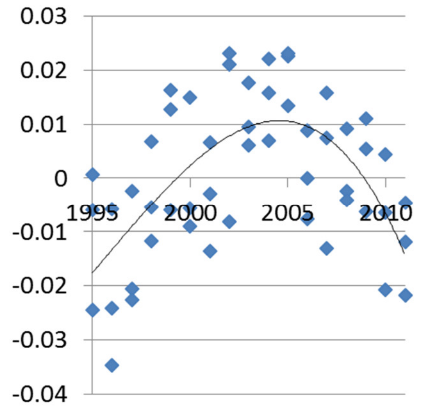
Effects Specification			
Cross-section fixed (dummy variables)			
Weighted Statistics			
R-squared	0.976423	Mean dependent var	0.324190
Adjusted R-squared	0.974383	S.D. dependent var	0.201593
S.E. of regression	0.021798	Sum squared resid	0.148249
F-statistic	478.5672	Durbin-Watson stat	0.717904
Prob(F-statistic)	0.000000		
Unweighted Statistics			
R-squared	0.968986	Mean dependent var	0.251643
Sum squared resid	0.151740	Durbin-Watson stat	0.754697

Source: authors calculations, Eviews

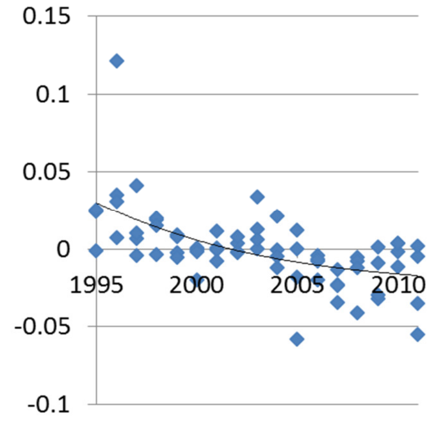
The model was validated by the characteristics of the fitted model. R^2 is 0.976423 and Adjusted R–squared is 0.974383. R–squared is very high due to its estimation specific for pooled data series as noted in the Chapter 2. The adjusted R^2 is by 0.00204 points smaller than R^2, which confirms that there are no redundant variables there. The P-value of Student's test provided in the column 'Prob' was used to determine the significance of GDP, GDP squared, the share of a particular polluting industry, R&D, environmental taxes, energy taxes and percentage of companies that discloses ESG. Since the P–value is lower than 0.05, it indicates that these coefficients have a statistically significant explanatory power with the probability of 95%. As seen from the Table, F–statistics of the final extended quadratic model is 478.5672 and probability of F–statistics being zero is non–existant. In this case, Durbin–Watson stat is 0.717904, indicating substantial serial correlation of the residuals. In order to estimate the precision of the model, the chart of the residuals is analysed in detail. This analysis should provide a deeper insight into the country's differences and if it could be proved, that error terms are similar in the specific groups of the countries, this could indicate the additional factors for the analysis of GHG – GDP relationship. The residuals of all analysed countries provided by Eviews is presented in Annex F. After the analysis of these charts, it was observed that the charts of the state's residual has some similarities in the countries belonging to the same groups as described in Chapter 3.1. Based on these tendencies, it was decided to redraw the charts, grouping them into six groups as follows: the Baltic region (Lithuania, Latvia and Estonia), Central and Eastern Europe (Poland, Slovakia, Slovenia and Hungary), Southern Europe (Greece, Spain and Portugal), Western Europe I (Denmark, Belgium, France and Germany), Western Europe II (Austria, Netherland and Sweden) and Western Europe III (Italy, Ireland and UK). Taking the residual numbers produced by Eviews, the countries were grouped into six groups and the cubic trend line was added using MS Excel in order to better represent the specific patterns (Fig 10).



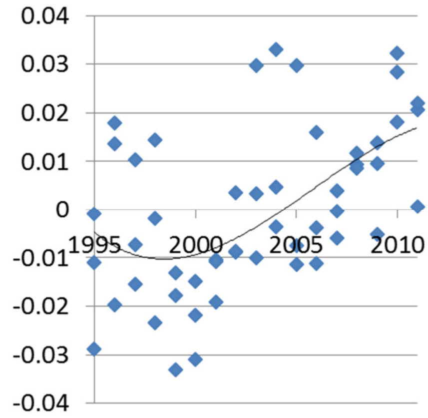
R – 0.5165. Lithuania, Latvia and Estonia



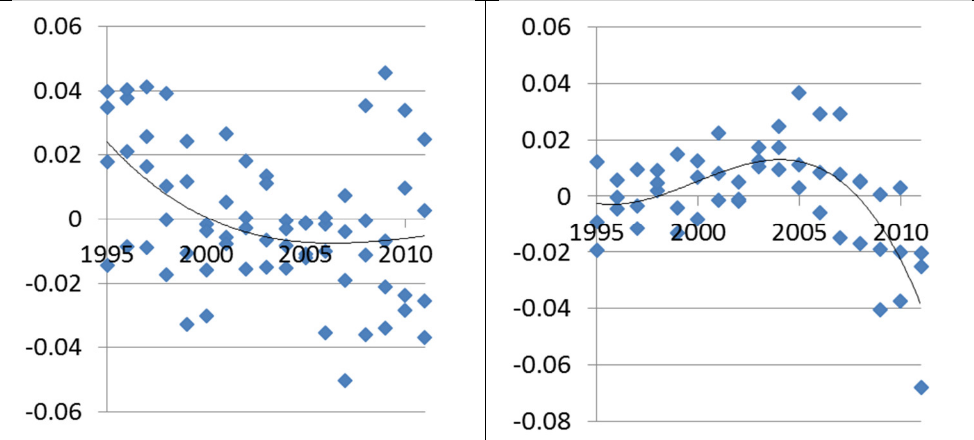
R – 0.418. Greece, Spain and Portugal



R – 0.357. Denmark, Belgium, France and Germany



R – 0.3059. Austria, Netherland and Sweden



R – 0.1859. Poland, Slovakia, Slovenia and Poland

R – 0.5104. Italy, Ireland and UK

Fig. 10. The remaining error terms of the model. *Source*: made by author

In five models, R^2 of the trend line and the plotted residuals are around 0.5, indicating that the modelled trend lines reasonably well capture the residual variation. Residual from CEE countries model have not shown the particular pattern and its R^2 is only 0.1859. While the group of the Baltic States and Southern countries the fit of countries is particularly good. The Baltic countries indicate the "U" pattern while Southern countries demonstrate a clear pattern of the "inverted U". This indicates that, in the case of the Baltic States in general, and, specifically, Lithuania, the increase in the growth of GHG with GDP will be larger than that estimated by the overall EKC model, and additional measures should be taken to limit the GHG growth. On the other hand, when the development level of Southern countries is reached, one can expect that the turnaround in the trend, to be faster and steeper as indicated in "inverted U" pattern of Southern countries error terms.

The evaluation of the statistical significance of the final results is based on the analysis of the signs of the coefficients.

Table 13. Comparison of expected and obtained coefficient signs

Short name	Description	Signs of coefficients	
		Expected sign	Final results
SECT	The share of a particular polluting industry	Positive	Positive
RD	R&D	Negative	Positive
TAX1	Environmental taxes	Negative	Positive
ENERGTAX	Energy t axes	Negative	Negative
ESGCORP	ESG score	Negative	Negative

Source: made by author

In general, it can be seen in Table 12 that the considered indicators produce a statistically significant effect. The regression coefficients referring to economic structure, research and development expenditure and environmental tax have a positive sign, while energy tax and ESG score have a negative sign.

We was expected to get a positive sign of the economic structure and it had been obtained. The size of agriculture, industry and construction negatively impacts the level of GHG.

It has been mentioned that the results of R&D impact are not likely to meet the expectation of getting a negative sign. The obtained positive sign in the model shows that the increase in R&D leads to a rise of the GHG level. In further investigation, it will be interesting to analyse the structure of R&D in detail and, possibly, to include some lag of R&D in GDP.

An effective measure used in the environmental policy is associated with the environmental taxes. However, the result is not straightforward: the regression coefficient of the energy taxes has an expected negative sign, but the environmental taxes does not have the expected impact, since the coefficient of the environmental taxes has a positive sign in the model, implying that higher taxes result in a higher GHG level. This may be explained by the fact that the category of overall environmental taxes is too broad, and not necessarily directed to regulate the level of GHG.

In fact, the extended model has improved the statistical characteristics of the model. In mathematical logic the extended model is not valid to estimate the existence of EKC form because the additional variables incorporated in the equation change the format of a function. However, the signs of the coefficients by $GDP > 0$ and $GDP^2 < 0$ indicate that it could be a form of the inverted U.

The existence of differences between the pollution levels in different countries in the model is demonstrated by the differences between a country's intercepts (i.e. the height of EKC). In the reduced model (Table 10), the minimum intercept was fixed in Latvia at 0.244088 and maximum – in Ireland, at 0.289948. In the extended model (Table 12), the minimum intercept was also fixed in Latvia at – 0.198776 and maximum – in Ireland, at 0.201031. It can be observed that the differences between the minimum and maximum points have been reduced from 0.534036 to 0.399807.

The factors added to the model could increase its efficiency because the additional variables, demonstrating the statistical significance, reduce the area of the error term. A measure indicating the statistical properties of an error term is 'Sum squared residuals'. In the reduced model, it was 0.291873, while in the extended model, it reached 0.291873, the decrease of number indicates a decrease in countries differences unexplained by the considered factors.

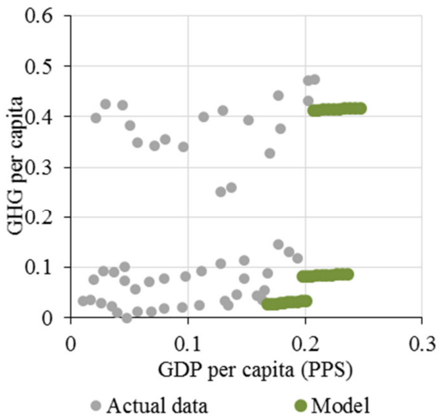
The obtained model coefficient estimates was used as a basis to estimate several scenarios, in order to see the potential future path of EKC development. Three general scenarios were tested, where average economic growth, increase in Energy tax and decrease in the heavy polluting industries. The scenarios are presented in the Tables 14–16.

The analysis of the first scenario has shown that the GDP increase of about 2% per year for the period 2014–2024 is not sufficient for decreasing GHG emissions in the Baltic and Central and Eastern European countries (the Baltic States, Central and Eastern Europe, Greece and Portugal) because these countries have not yet reached the EKC turning point. These countries need and some additional environmental measures (including changes in the structure of the economy, energy taxes and others) and further sustainable business development. The analysis of the second scenario has shown that the GDP increase of about 2% per year and the increase of energy taxes of about 1% per year will result in the decrease of GHG emissions in many analysed countries except for Lithuania, Latvia, Poland, and Hungary. The analysis of the third scenario has shown that the GDP increase of about 2% per year and polluting sectors' decline of about 1% per year will result in the decrease of GHG level in the whole sample.

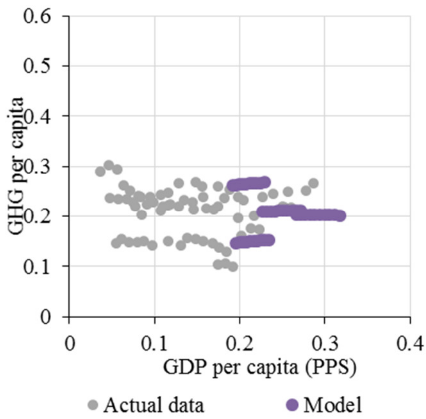
Table 14. Potential scenarios estimates (scenario 1)

Scenario 1. Average GDP growth 2 percent per year

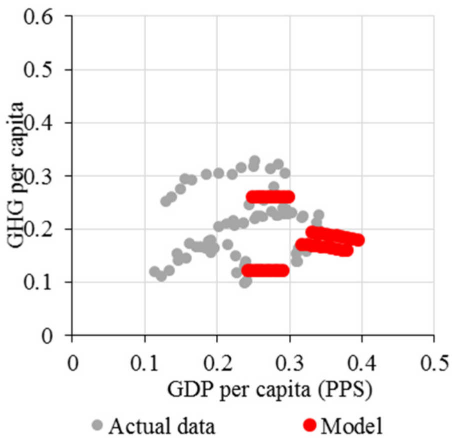
The Baltic states



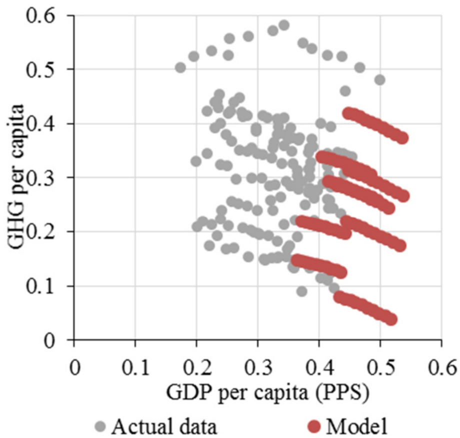
Central and Eastern Europe



Southern Europe



Western Europe

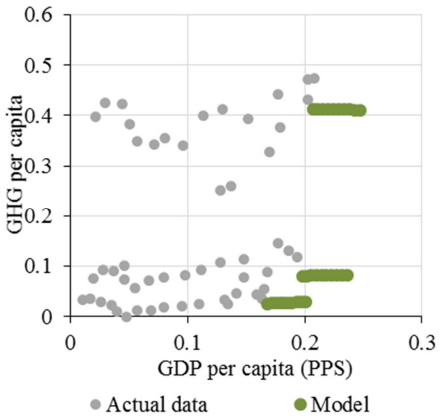


Source: made by author

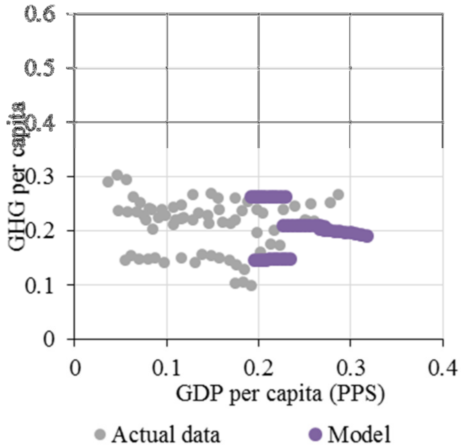
Table 15. Potential scenarios estimates (scenario 2)

Scenario 2. Average GDP growth 2 percent per year and increase in Energy tax 1 percentage per year

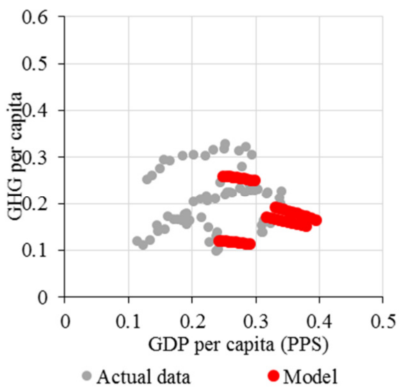
The Baltic states



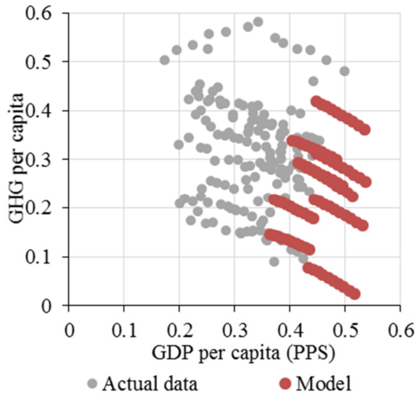
Central and Eastern Europe



Southern Europe



Western Europe

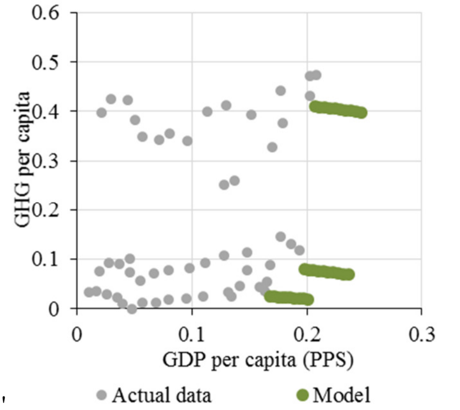


Source: made by author

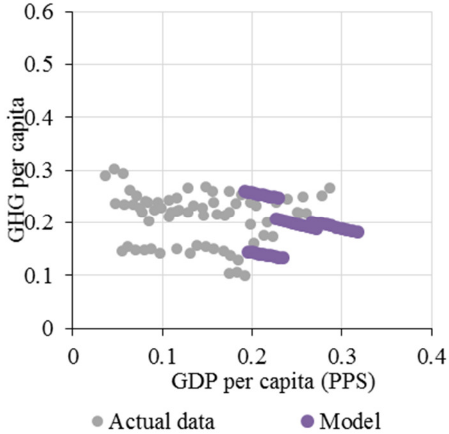
Table 16. Potential scenarios estimates (scenario 3)

Scenario 3. Average GDP growth 2 percent per year and decrease in manufacturing sector by 1 percentage per year

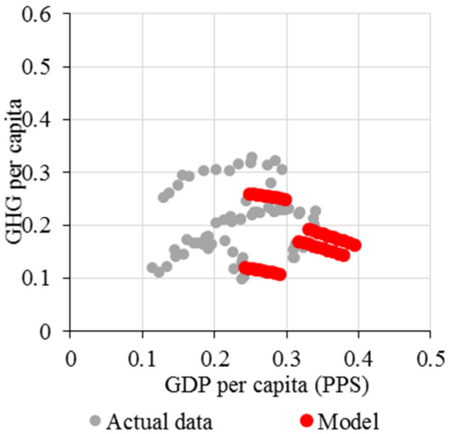
The Baltic states



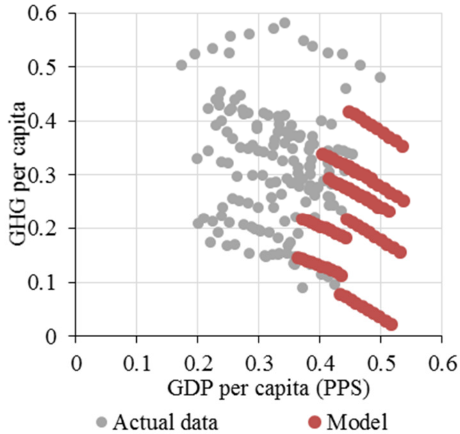
Central and Eastern Europe



Southern Europe



Western Europe



Source: made by author

For further analysis, it was assumed that, the environmental incentives, comprising various voluntary activities of business, should lead to a lower level of the states' GHG. In this research the data of the companies' sustainability performance (referring to Environmental, Social and Corporate Governance performance) is taken from the Bloomberg platform. The investigation results were assessed by continuing the empirical analysis of the previous research, including ESG score as the additional factor. In this research, the percentage of the listed companies, in a country's Exchange, following ESG policy, was taken as a proxy of a country's ESG estimation. The accounting data and external information have been taken from the Bloomberg platform. In the Bloomberg database system the ESG data are available only for the period of 2007–2011. As this is a shorter period than all other data used in the models, the same model has been recalculated to cover only the period of 2007–2011 in order to track the differences related to a shortened period. The statistical information provided by Eviews is given in Annex F. It can be seen that the shortened period has not impacted the previously discussed results. Then, another model was calculated, including the ESG variable as an additional factor "ESGCORP", the information is given below in Table 17.

Table 17. Regression parameter estimates for the extended model

Dependent Variable: NNGGE_?
Method: Pooled EGLS (Cross-section weights)
Date: 02/21/14 Time: 15:33
Sample: 2007 2011
Included observations: 5
Cross-sections included: 19
Total pool (balanced) observations: 95
Linear estimation after one-step weighting matrix
White cross-section standard errors & covariance (no d.f. correction)
WARNING: estimated coefficient covariance matrix is of reduced rank

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.076163	0.030487	-2.498211	0.0149
NNGDP2_?	0.928361	0.132445	7.009432	0.0000
NNGDP2_?^2	-1.066884	0.239128	-4.461555	0.0000
RD_?	0.000153	4.04E-05	3.779087	0.0003
TAX1_?	0.046852	0.004543	10.31257	0.0000
ENERGTAX_?	-0.001016	9.54E-05	-10.65000	0.0000
ESGCORP_?	-0.134185	0.047702	-2.813010	0.0064
SECT_?	0.004906	0.001154	4.249698	0.0001
CRIS08	-0.010869	0.001333	-8.152431	0.0000
CRIS	-0.023568	0.004078	-5.779022	0.0000
Fixed Effects (Cross)				
LITHUANIA--C	-0.082906			
LATVIA--C	-0.133673			
ESTONIA--C	0.205401			
GREECE--C	0.120642			
SPAIN--C	-0.033893			
ITALY--C	0.018140			
PORTUGAL--C	-0.050358			
DENMARK--C	0.057881			
BELGIUM--C	0.037501			

FRANCE--C	-0.042789
GERMANY--C	0.033079
NETHERLANDS--C	0.052078
AUSTRIA--C	-0.075286
SWEDEN--C	-0.171198
UK--C	0.110021
IRELAND--C	0.121970
POLAND--C	0.028713
SLOVENIA--C	-0.060985
HUNGARY--C	-0.134337

Effects Specification			
Cross-section fixed (dummy variables)			
Weighted Statistics			
R-squared	0.992823	Mean dependent var	0.380004
Adjusted R-squared	0.989930	S.D. dependent var	0.239368
S.E. of regression	0.016309	Sum squared resid	0.017820
F-statistic	343.2581	Durbin-Watson stat	1.802140
Prob(F-statistic)	0.000000		
Unweighted Statistics			
R-squared	0.981693	Mean dependent var	0.228189
Sum squared resid	0.020181	Durbin-Watson stat	1.805564

R–squared is 0.992823 and Adjusted R–squared is 0.989930. The P–value of the coefficients of all selected variables is lower than 0.05, which indicates that these coefficients have a statistically significant explanatory power with the probability of 95%. As can be observed from the Table, F–statistics of the final extended quadratic model is 343.2581 and the probability of F–statistics being zero is non-existent. It this case, Durbin–Watson stat is 1.802140, indicating a substantially smaller serial correlation of the residuals. This result may be explained by the fact that only a shorter period was considered, and the analysis of the residuals was not performed.

The regression coefficients next to ESG score have a negative sign, which means that a higher number of such enterprises leads to lower a level of GHG. This short ESG policy analysis shows that the number of ESG corporations influences the height of the EKC curve. The concept of ESG and, specifically, its quantitative evaluation are still completely new, and there is no consensus on the methods of its estimation. Deeper discussions and analysis in this area should be of interest for further research.

Further analysis might be extended into some other areas. Using the proposed technique other environmental variables could be tested. The impact of different additional indicators could be estimated with the aim to analyse specific issues. Unfortunately, in many cases, further analysis is limited to the available data and their consistency over time. Other direction of studies may be related to the deeper analysis of the economic shocks (e.g. the financial crisis of 2008) with respect to the EKC relationship.

3.4. Conclusions to Chapter 3

The existence of EKC for twenty two European countries was tested based on the analysis of the EKC problem. Econometric analysis was performed in three main steps.

1. Firstly, the effectiveness of using the cubic model of the reduced form EKC was estimated for individual countries. The result was statistically significant for only twenty (out of twenty two) countries, which were chosen for the second step of analysis. It can be seen that, in general, the research confirmed the validity of the inverse U–shaped relationship for these countries. The analysis of individual equations and the estimated coefficients showed different relationship patterns for various states. However, some countries, representing similar development levels or geographic areas, have some similarities in patterns. The visual inspection shows that, for the period of 1995–2008, the investigated countries, depending on their development stage, are at the beginning, top upward or downward sloping EKC part of the section. The countries belonging to the region of Central and Eastern Europe, as well as the Baltic region, demonstrate slight differences, but the patterns of their EKC curves are similar, showing that GHG increases with the increase in GDP (the initial EKC section). The curves for the countries of Southern Europe refer to the middle EKC section. The countries of Western Europe refer to the last EKC section, where GHG level decreases with the increase of GDP. These trends may indicate that the considered countries will probably follow the relationship of the general EKC form in the long run development, although some specific geographic or economic features of the considered countries will remain.
2. Secondly, the reduced form EKC estimate evaluated by the fixed effect panel model for twenty countries confirms the presence of the inverse U–shaped relationship between GHG and GDP, indicating that, at a particular level of GDP and economic growth, the pollution increases, but after reaching some threshold, the trend reverses so that, at a higher

development stage, further economic growth results in the improvement of the environment. The obtained data allows us to conclude, that the considered countries develop in a similar way and all should analyse various instruments, which could help them to control the level of GHG on their path to economic growth. On the other hand, the developing countries could implement the instruments used by the developed countries and introduce some new ones for reducing the EKC height.

3. Finally, the extended EKC estimation model by the fixed effect panel model for the whole sample suggests that the selected indicators (e.g. the share of a particular polluting industry, R&D, environmental taxes, energy taxes and percentage of companies that discloses ESG) are the factors relevant for managing the process of climate change as they demonstrate a statistically significant effect, but not all of them then tested result in relationship expected by economic logic. The size of agriculture, industry and construction negatively impacts the level of GHG. The regression coefficients next to energy taxes and ESG score have a negative sign, which means that a higher value of these indicators is associated with a lower level of GHG. The obtained positive signs of R&D and environmental taxes in the model show that the increase in the values of these variables leads to a rise of the GHG level, which is opposite to the initially expected one. It should be noted that the estimation results might not be obvious in the case of R&D expenditure, as this in general, increases with economic growth and the selected model's estimates for various countries representing different starting points of R&D expenditure. In the case of the environmental tax coefficient, the unexpected result may be explained by the fact that the category of overall environment taxes is too broad, and not necessarily directed to regulate the GHG level.

General Conclusions

1. At the scientific level, one of the approach for analysing the impact of the economic growth on the environmental degradation is the environmental Kuznets curves, which could be a methodology for evaluating socio–economic and environmental policies, affecting the examined relationship. The performed thorough analysis of the empirical studies in the considered area aimed at determining main factors, influencing the EKC shape in a country, has shown that they can differ and their effect can also vary. The main factors having a strong influence on the form of the EKC are as follows: the scale of economic activities, the structure of economy, technological development, international trade, income inequality, social–demographical factors, historical events or shocks and some country–specific factors. At any period the EKC is influenced not by a single factor, but by their entity. In most of the analysed cases, the results confirmed the dominance of inverted U relationship, while some of them indicated other trends.
2. The issues related to the climate change are among the highest priorities of the international environmental policy. The impact of the climate change on economic and social development of a country is controversial, manifesting itself in various areas and producing long–term effects. It may require substantial investment to the harmful affects of climate change and compensation for the experienced losses, which differ in different geographical regions. The estimation of the affects produced on GHG by

economic growth and related various external factors on GHG can be viewed as a country's strategic decision supporting tool. In this work, the reduced–form EKC has been used as a model, allowing us to understand how economic growth affects the environment. The extended analysis, covering the relevant factors, which influence the structure of the economy, technological development, environmental and energy taxes and sustainable business, allows us to assess the impact of economic growth on GHG emissions, combining the proposed measures in modelling the possible development scenarios in order to reduce the harmful effect of economic growth on the environment.

3. The initial empirical analysis of the impact of the economic growth on GHG emissions in the EU countries has shown that the trend of the development presented in the form of EKC varies depending on the level of the development of a particular country. The analysed countries in the region may be subdivided into four groups according to the shape of the EKC:
    - The Baltic, and some Central and Eastern European countries, where amounts of GHG emissions are increasing in a course of economic growth, but the continued economic growth impacts on decreasing of GHG emissions;
    - The countries of Southern Europe demonstrate the trend, where the EKC curve has reached the turning point and start decreasing;
    - Most of the countries of Western Europe, where the increase in GDP leads to the decreasing levels of GHG;
    - Ireland (as rapidly growing economy), which demonstrates a complete inverse U–shaped relationship between GHG and GDP.
4. The empirical investigation has revealed that the economic structure, research and development expenditure, as well as the environmental taxes, energy taxes and ESG score could describe the height of the EKC, however, the direction determined by estimating two variables (research and development expenditure and environmental tax) does not correspond to economic logic.
5. The analysis of several scenarios has shown that the GDP increase of–about 2% per year during the ten-year period obtained in the theoretical case, is not sufficient to decrease GHG emissions in the Baltic and Central and Eastern European countries. These countries need some environmental measures to be taken (the indicators tested in the case included changes in the structure of the economy and energy taxes) and further sustainable business development.

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ANNEXES

Annex A. The Normalised Data of Gross Domestic Product and Greenhouse Gas Emissions

Table A.1. GDP per capita in PPS and normalised GDP per capita in PPS

	gdp2_Belgium	gdp2_Bulgaria	gdp2_Czech Republic	gdp2_Denmark	gdp2_Germany	gdp2_Estonia	gdp2_Ireland	gdp2_Greece	gdp2_Spain	gdp2_France	gdp2_Italy	gdp2_Cyprus	gdp2_Latvia	gdp2_Lithuania	gdp2_Luxembourg	gdp2_Hungary	gdp2_Netherlands	gdp2_Austria	gdp2_Poland	gdp2_Portugal	gdp2_Romania	gdp2_Slovenia	gdp2_Slovakia	gdp2_Finland	gdp2_Sweden	gdp2_UK
1995	18.900	4.600	11.200	19.300	18.900	5.300	15.200	12.300	13.400	17.000	17.800	12.800	4.600	5.200	32.600	7.500	18.100	19.700	6.300	11.300	5.100	10.900	7.000	15.800	18.300	16.900
1996	19.400	3.900	12.100	20.400	19.500	5.800	16.700	12.900	14.200	17.600	18.600	13.300	5.000	5.700	34.100	7.900	19.200	20.700	6.900	11.900	5.100	11.700	7.700	16.300	19.200	18.100
1997	20.400	4.200	12.300	21.600	20.100	6.800	18.600	13.700	15.100	18.600	19.400	13.800	5.600	6.300	34.900	8.500	20.600	21.400	7.600	12.700	4.800	12.700	8.300	17.900	20.100	19.500
1998	20.900	4.700	12.300	22.400	20.700	7.200	20.500	14.100	16.200	19.500	20.400	14.600	6.200	6.900	37.000	9.100	21.800	22.400	8.100	13.500	4.500	13.400	8.800	19.300	20.900	20.300
1999	21.900	4.900	12.800	23.300	21.600	7.600	22.500	14.700	17.100	20.400	21.100	15.500	6.500	6.900	42.400	9.600	23.300	23.500	8.600	14.500	4.700	14.400	9.000	20.400	22.500	21.200
2000	24.000	5.400	13.500	25.100	22.400	8.600	25.100	16.000	18.500	21.900	22.400	16.700	7.000	7.500	46.600	10.300	25.600	25.100	9.200	15.500	5.000	15.300	9.500	22.300	24.300	22.900
2001	24.500	5.900	14.500	25.300	22.900	9.200	26.300	17.100	19.400	22.800	23.400	17.800	7.600	8.300	46.200	11.500	26.400	24.900	9.400	15.900	5.500	15.800	10.400	22.800	24.200	23.900
2002	25.700	6.500	15.000	26.300	23.400	10.200	28.300	18.400	20.600	23.600	23.000	18.100	8.400	9.100	49.100	12.500	27.300	26.000	9.900	16.400	6.000	16.900	11.100	23.500	25.000	24.800
2003	25.600	7.000	15.900	25.700	24.000	11.300	29.300	19.200	20.900	23.100	23.000	18.300	9.100	10.300	51.200	13.000	26.800	26.500	10.100	16.400	6.500	17.300	11.500	23.300	25.700	25.400
2004	26.300	7.500	16.900	27.200	25.000	12.400	30.900	20.300	21.900	23.700	23.200	19.700	10.100	11.200	54.600	13.600	28.000	27.700	10.900	16.700	7.400	18.800	12.300	25.200	27.400	27.000
2005	27.000	8.200	17.800	27.800	26.100	13.800	32.500	20.400	22.900	24.700	23.700	20.900	11.100	12.300	57.100	14.200	29.400	28.200	11.500	17.900	7.900	19.600	13.500	25.700	27.400	27.900
2006	27.900	9.000	18.900	29.300	27.300	15.600	34.400	21.800	24.800	25.600	24.700	22.000	12.500	13.600	63.900	14.900	31.000	29.800	12.300	18.700	9.100	20.700	15.000	27.000	29.100	28.900
2007	28.900	10.000	20.700	30.600	28.900	17.500	36.500	22.500	26.200	26.900	26.000	23.600	14.300	15.500	68.500	15.400	33.100	30.900	13.600	19.600	10.400	22.100	16.900	29.400	31.200	29.500
2008	29.000	10.900	20.200	31.100	29.000	17.200	32.900	23.100	25.900	26.700	26.100	24.900	14.600	16.100	65.900	16.000	33.600	31.200	14.100	19.500	11.700	22.700	18.100	29.800	31.000	28.600
2009	27.700	10.300	19.400	29.000	27.000	15.000	30.200	22.100	24.200	25.600	24.400	23.500	12.700	13.600	60.000	15.300	31.000	29.500	14.200	18.800	11.100	20.300	17.100	26.900	28.200	26.300
2010	29.200	10.700	19.500	31.300	29.000	15.500	31.300	21.200	24.200	26.500	24.700	23.600	13.200	14.900	65.200	15.900	32.000	31.100	15.300	19.700	11.400	20.500	17.900	27.700	30.200	27.500
2011	29.900	11.600	20.100	31.500	30.500	17.200	32.600	19.900	24.300	27.300	25.100	23.700	14.700	16.600	68.100	16.500	32.700	32.400	16.200	19.500	11.800	21.000	18.500	28.700	31.700	27.700

	nngdp2_Belgium	nngdp2_Bulgaria	nngdp2_Czech Republic	nngdp2_Denmark	nngdp2_Germany	nngdp2_Estonia	nngdp2_Ireland	nngdp2_Greece	nngdp2_Spain	nngdp2_France	nngdp2_Italy	nngdp2_Cyprus	nngdp2_Latvia	nngdp2_Lithuania	nngdp2_Luxembourg	nngdp2_Hungary	nngdp2_Netherlands	nngdp2_Austria	nngdp2_Poland	nngdp2_Portugal	nngdp2_Romania	nngdp2_Slovenia	nngdp2_Slovakia	nngdp2_Finland	nngdp2_Sweden	nngdp2_UK
1995	0,23	0,01	0,11	0,24	0,23	0,02	0,17	0,13	0,15	0,20	0,21	0,14	0,01	0,02	0,44	0,05	0,22	0,24	0,04	0,11	0,02	0,11	0,05	0,18	0,22	0,20
1996	0,24	0,00	0,13	0,25	0,24	0,03	0,20	0,14	0,16	0,21	0,22	0,14	0,02	0,03	0,46	0,06	0,23	0,26	0,05	0,12	0,02	0,12	0,06	0,19	0,23	0,22
1997	0,25	0,00	0,13	0,27	0,25	0,04	0,22	0,15	0,17	0,22	0,24	0,15	0,03	0,04	0,47	0,07	0,25	0,27	0,06	0,13	0,01	0,13	0,07	0,21	0,25	0,24
1998	0,26	0,01	0,13	0,28	0,26	0,05	0,25	0,16	0,19	0,24	0,25	0,16	0,04	0,05	0,51	0,08	0,27	0,28	0,06	0,15	0,01	0,15	0,07	0,24	0,26	0,25
1999	0,27	0,02	0,14	0,30	0,27	0,06	0,28	0,16	0,20	0,25	0,26	0,18	0,04	0,05	0,59	0,09	0,30	0,30	0,07	0,16	0,01	0,16	0,08	0,25	0,28	0,26
2000	0,31	0,02	0,15	0,32	0,28	0,07	0,32	0,18	0,22	0,27	0,28	0,20	0,05	0,05	0,65	0,10	0,33	0,32	0,08	0,18	0,02	0,17	0,09	0,28	0,31	0,29
2001	0,31	0,03	0,16	0,33	0,29	0,08	0,34	0,20	0,24	0,29	0,30	0,21	0,06	0,07	0,65	0,12	0,34	0,32	0,08	0,18	0,02	0,18	0,10	0,29	0,31	0,31
2002	0,33	0,04	0,17	0,34	0,30	0,10	0,37	0,22	0,25	0,30	0,29	0,22	0,07	0,08	0,69	0,13	0,36	0,34	0,09	0,19	0,03	0,20	0,11	0,30	0,32	0,32
2003	0,33	0,05	0,18	0,33	0,31	0,11	0,39	0,23	0,26	0,29	0,29	0,22	0,08	0,10	0,72	0,14	0,35	0,35	0,09	0,19	0,04	0,20	0,12	0,30	0,33	0,33
2004	0,34	0,05	0,20	0,36	0,32	0,13	0,41	0,25	0,27	0,30	0,29	0,24	0,09	0,11	0,77	0,15	0,37	0,36	0,11	0,20	0,05	0,23	0,13	0,33	0,36	0,35
2005	0,35	0,07	0,21	0,36	0,34	0,15	0,44	0,25	0,29	0,32	0,30	0,26	0,11	0,13	0,81	0,16	0,39	0,37	0,12	0,21	0,06	0,24	0,15	0,33	0,36	0,37
2006	0,37	0,08	0,23	0,39	0,36	0,18	0,47	0,27	0,32	0,33	0,32	0,28	0,13	0,15	0,92	0,17	0,41	0,40	0,13	0,23	0,08	0,26	0,17	0,35	0,38	0,38
2007	0,38	0,09	0,26	0,41	0,38	0,21	0,50	0,28	0,34	0,35	0,34	0,30	0,16	0,18	0,99	0,18	0,45	0,41	0,15	0,24	0,10	0,28	0,20	0,39	0,42	0,39
2008	0,38	0,11	0,25	0,42	0,38	0,20	0,44	0,29	0,34	0,35	0,34	0,32	0,16	0,19	0,95	0,18	0,45	0,42	0,16	0,24	0,12	0,29	0,22	0,40	0,41	0,38
2009	0,36	0,10	0,24	0,38	0,35	0,17	0,40	0,28	0,31	0,33	0,31	0,30	0,13	0,15	0,86	0,17	0,41	0,39	0,16	0,23	0,11	0,25	0,20	0,35	0,37	0,34
2010	0,39	0,10	0,24	0,42	0,38	0,18	0,42	0,26	0,31	0,35	0,32	0,30	0,14	0,17	0,94	0,18	0,43	0,42	0,17	0,24	0,11	0,25	0,21	0,36	0,40	0,36
2011	0,40	0,12	0,25	0,42	0,41	0,20	0,44	0,24	0,31	0,36	0,32	0,30	0,16	0,19	0,98	0,19	0,44	0,44	0,19	0,24	0,12	0,26	0,22	0,38	0,42	0,36

Table A.2. GHG per capita and normalised GHG per capita

	gge_Belgium	gge_Bulgaria	gge_Czech Republic	gge_Denmark	gge_Germany	gge_Estonia	gge_Ireland	gge_Greece	gge_Spain	gge_France	gge_Italy	gge_Cyprus	gge_Latvia	gge_Lithuania	gge_Luxembourg	gge_Hungary	gge_Netherlands	gge_Austria	gge_Poland	gge_Portugal	gge_Romania	gge_Slovenia	gge_Slovakia	gge_Finland	gge_Sweden	gge_UK
1995	14,85	9,00	14,58	14,60	13,72	13,84	16,40	10,32	7,95	9,30	9,33	11,57	5,03	6,06	25,09	7,77	14,47	10,04	11,21	7,15	7,61	9,31	9,93	13,90	8,44	12,23
1996	15,23	9,03	14,99	16,95	13,90	14,52	16,87	10,53	7,74	9,51	9,22	12,00	5,10	6,46	24,88	7,99	14,93	10,40	11,54	6,91	7,74	9,65	9,89	14,97	8,86	12,55
1997	14,34	8,64	14,72	15,06	13,43	14,45	17,12	10,90	8,26	9,39	9,32	11,92	4,92	6,42	22,87	7,83	14,43	10,33	11,31	7,19	7,17	9,84	9,89	14,66	8,28	12,07
1998	14,86	8,10	14,06	14,28	13,11	13,48	17,70	11,36	8,49	9,61	9,52	11,90	4,75	6,68	20,48	7,79	14,41	10,24	10,57	7,65	6,46	9,73	9,75	13,92	8,34	12,01
1999	14,22	7,33	13,26	13,71	12,70	12,64	17,76	11,29	9,16	9,34	9,63	12,20	4,47	6,01	21,21	7,83	13,54	10,01	10,31	8,42	5,82	9,43	9,53	13,78	7,95	11,44
2000	14,26	7,26	14,19	12,80	12,66	12,49	18,05	11,58	9,46	9,23	9,68	12,42	4,23	5,59	22,51	7,67	13,43	10,02	10,07	8,27	5,95	9,52	9,13	13,41	7,78	11,46
2001	14,17	7,69	14,19	13,06	12,83	12,82	18,31	11,64	9,37	9,13	9,78	12,14	4,52	5,94	23,37	7,87	13,42	10,50	9,99	8,20	6,07	9,94	9,73	14,39	7,84	11,49
2002	14,00	7,56	13,87	12,90	12,54	12,44	17,50	11,58	9,66	8,98	9,80	12,36	4,54	6,11	24,86	7,68	13,26	10,65	9,65	8,55	6,33	10,00	9,52	14,77	7,90	11,10
2003	14,12	8,21	14,17	13,75	12,50	13,89	17,24	11,89	9,66	9,02	10,01	12,72	4,66	6,20	25,49	8,01	13,24	11,34	10,00	7,97	6,66	9,85	9,58	16,26	7,92	11,18
2004	14,16	8,16	14,29	12,64	12,35	14,19	16,93	11,90	9,88	8,93	9,97	12,75	4,75	6,45	28,23	7,96	13,26	11,24	10,12	8,18	6,55	10,00	9,55	15,45	7,80	11,13
2005	13,72	8,21	14,21	11,81	12,10	13,71	16,89	12,17	10,06	8,89	9,83	12,43	4,81	6,81	28,39	7,87	12,85	11,33	10,22	8,36	6,54	10,17	9,40	13,13	7,46	10,96
2006	13,18	8,36	14,34	13,22	12,14	13,33	16,40	11,81	9,70	8,64	9,59	12,47	5,05	6,98	27,60	7,75	12,58	10,91	10,64	7,85	6,75	10,26	9,37	15,24	7,42	10,83
2007	12,63	8,92	14,35	12,33	11,86	15,68	15,86	12,01	9,71	8,42	9,39	12,60	5,30	7,73	25,95	7,55	12,48	10,53	10,70	7,60	6,62	10,29	9,00	14,86	7,19	10,59
2008	12,81	8,76	13,69	11,65	11,86	14,63	15,36	11,62	8,81	8,30	9,08	12,75	5,09	7,40	25,19	7,33	12,39	10,45	10,50	7,39	6,52	10,65	9,09	13,25	6,90	10,30
2009	11,58	7,60	12,75	11,04	11,11	12,13	13,89	10,98	7,91	7,89	8,17	12,30	4,81	6,10	23,69	6,72	12,00	9,57	9,98	7,08	5,60	9,56	8,12	12,40	6,41	9,36
2010	12,16	7,98	13,08	11,06	11,53	14,92	13,76	10,37	7,58	7,95	8,29	11,53	5,35	6,34	24,40	6,78	12,62	10,15	10,52	6,71	5,43	9,52	8,46	13,93	7,01	9,58
2011	10,92	8,97	12,73	10,12	11,21	15,64	12,58	10,17	7,59	7,47	8,06	10,90	5,54	7,08	23,64	6,62	11,67	9,86	10,37	6,62	5,76	9,52	8,40	12,47	6,53	8,84

	nngge_Belgium	nngge_Bulgaria	nngge_Czech Republic	nngge_Denmark	nngge_Germany	nngge_Estonia	nngge_Ireland	nngge_Greece	nngge_Spain	nngge_France	nngge_Italy	nngge_Cyprus	nngge_Latvia	nngge_Lithuania	nngge_Luxembourg	nngge_Hungary	nngge_Netherlands	nngge_Austria	nngge_Poland	nngge_Portugal	nngge_Romania	nngge_Slovenia	nngge_Slovakia	nngge_Finland	nngge_Sweden	nngge_UK
1995	0,44	0,20	0,43	0,43	0,39	0,40	0,50	0,25	0,15	0,21	0,21	0,30	0,03	0,08	0,86	0,15	0,42	0,24	0,29	0,12	0,14	0,21	0,24	0,40	0,17	0,33
1996	0,46	0,20	0,45	0,53	0,40	0,43	0,52	0,26	0,15	0,22	0,21	0,32	0,04	0,09	0,85	0,16	0,44	0,26	0,30	0,11	0,15	0,22	0,23	0,44	0,19	0,34
1997	0,42	0,18	0,43	0,45	0,38	0,42	0,53	0,28	0,17	0,21	0,21	0,32	0,03	0,09	0,77	0,15	0,42	0,25	0,29	0,12	0,12	0,23	0,23	0,43	0,17	0,32
1998	0,44	0,16	0,41	0,42	0,37	0,38	0,56	0,30	0,18	0,22	0,22	0,32	0,02	0,10	0,67	0,15	0,42	0,25	0,26	0,14	0,09	0,23	0,23	0,40	0,17	0,32
1999	0,41	0,13	0,37	0,39	0,35	0,35	0,56	0,29	0,20	0,21	0,22	0,33	0,01	0,07	0,70	0,15	0,39	0,24	0,25	0,17	0,07	0,22	0,22	0,40	0,15	0,30
2000	0,42	0,13	0,41	0,35	0,35	0,34	0,57	0,30	0,22	0,21	0,23	0,34	0,00	0,06	0,76	0,14	0,38	0,24	0,24	0,17	0,07	0,22	0,20	0,38	0,15	0,30
2001	0,41	0,14	0,41	0,37	0,36	0,36	0,58	0,31	0,21	0,20	0,23	0,33	0,01	0,07	0,79	0,15	0,38	0,26	0,24	0,16	0,08	0,24	0,23	0,42	0,15	0,30
2002	0,40	0,14	0,40	0,36	0,34	0,34	0,55	0,30	0,22	0,20	0,23	0,34	0,01	0,08	0,85	0,14	0,37	0,27	0,22	0,18	0,09	0,24	0,22	0,44	0,15	0,28
2003	0,41	0,16	0,41	0,39	0,34	0,40	0,54	0,32	0,23	0,20	0,24	0,35	0,02	0,08	0,88	0,16	0,37	0,29	0,24	0,16	0,10	0,23	0,22	0,50	0,15	0,29
2004	0,41	0,16	0,42	0,35	0,34	0,41	0,53	0,32	0,23	0,19	0,24	0,35	0,02	0,09	0,99	0,15	0,37	0,29	0,24	0,16	0,10	0,24	0,22	0,46	0,15	0,29
2005	0,39	0,17	0,41	0,31	0,33	0,39	0,52	0,33	0,24	0,19	0,23	0,34	0,02	0,11	1,00	0,15	0,36	0,29	0,25	0,17	0,10	0,25	0,21	0,37	0,13	0,28
2006	0,37	0,17	0,42	0,37	0,33	0,38	0,50	0,31	0,23	0,18	0,22	0,34	0,03	0,11	0,97	0,15	0,35	0,28	0,27	0,15	0,10	0,25	0,21	0,46	0,13	0,27
2007	0,35	0,19	0,42	0,34	0,32	0,47	0,48	0,32	0,23	0,17	0,21	0,35	0,04	0,14	0,90	0,14	0,34	0,26	0,27	0,14	0,10	0,25	0,20	0,44	0,12	0,26
2008	0,36	0,19	0,39	0,31	0,32	0,43	0,46	0,31	0,19	0,17	0,20	0,35	0,04	0,13	0,87	0,13	0,34	0,26	0,26	0,13	0,10	0,27	0,20	0,37	0,11	0,25
2009	0,30	0,14	0,35	0,28	0,29	0,33	0,40	0,28	0,15	0,15	0,16	0,33	0,02	0,08	0,81	0,10	0,32	0,22	0,24	0,12	0,06	0,22	0,16	0,34	0,09	0,21
2010	0,33	0,16	0,37	0,28	0,30	0,44	0,39	0,25	0,14	0,15	0,17	0,30	0,05	0,09	0,83	0,11	0,35	0,25	0,26	0,10	0,05	0,22	0,18	0,40	0,12	0,22
2011	0,28	0,20	0,35	0,24	0,29	0,47	0,35	0,25	0,14	0,13	0,16	0,28	0,05	0,12	0,80	0,10	0,31	0,23	0,25	0,10	0,06	0,22	0,17	0,34	0,10	0,19

Annex B. The Results of Empirical Research in the Case of Lithuania

Table B.1. The results of empirical research in the case of Lithuania (Eviews)

Dependent Variable: NNGGE_?
Method: Pooled EGLS (Cross-section weights)
Date: 03/13/14 Time: 15:54
Sample: 1995 2008
Included observations: 14
Cross-sections included: 1
Total pool (balanced) observations: 14
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
NNGDP2_?	-1.290255	0.922635	-1.398446	0.1922
NNGDP2_?^2	13.52632	10.23603	1.321442	0.2158
NNGDP2_?^3	-30.97815	32.93330	-0.940633	0.3691
LITHUANIA--C	0.111016	0.022939	4.839571	0.0007

Weighted Statistics

R-squared	0.794035	Mean dependent var	0.093673
Adjusted R-squared	0.732246	S.D. dependent var	0.024352
S.E. of regression	0.012601	Sum squared resid	0.001588
F-statistic	12.85067	Durbin-Watson stat	1.582324
Prob(F-statistic)	0.000913		

Unweighted Statistics

R-squared	0.794035	Mean dependent var	0.093673
Sum squared resid	0.001588	Durbin-Watson stat	1.582324

Annex C. The Evaluation Results of the Reduced Cubic Model

Table C.1. The evaluation results of the reduced cubic model (Eviews)

Dependent Variable: NNGGE_?
Method: Pooled EGLS (Cross-section weights)
Date: 02/11/14 Time: 15:11
Sample: 1995 2011
Included observations: 17
Cross-sections included: 20
Total pool (balanced) observations: 340
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.257750	0.007491	34.40719	0.0000
NNGDP2_?	0.162947	0.116695	1.396355	0.1636
NNGDP2_?^2	-0.185218	0.610149	-0.303561	0.7617
NNGDP2_?^3	-1.413223	0.893331	-1.581970	0.1147
Fixed Effects (Cross)				
LITHUANIA--C	-0.175019			
LATVIA--C	-0.241011			
ESTONIA--C	0.127450			
GREECE--C	0.026165			
SPAIN--C	-0.066397			
ITALY--C	-0.042278			
PORTUGAL--C	-0.128796			
DENMARK--C	0.133252			
BELGIUM--C	0.149293			
FRANCE--C	-0.060585			
GERMANY--C	0.097873			
NETHERLANDS--C	0.151986			
AUSTRIA--C	0.029504			
SWEDEN--C	-0.091316			
UK--C	0.039091			
IRELAND--C	0.290326			
POLAND--C	-0.012242			
SLOVENIA--C	-0.035790			
SLOVAKIA--C	-0.059480			
HUNGARY--C	-0.132025			

Effects Specification

Cross-section fixed (dummy variables)

Weighted Statistics

R-squared	0.967752	Mean dependent var	0.295123

Adjusted R-squared	0.965514	S.D. dependent var	0.151680
S.E. of regression	0.030244	Sum squared resid	0.289953
F-statistic	432.4162	Durbin-Watson stat	0.721816
Prob(F-statistic)	0.000000		
	Unweighted Statistics		
R-squared	0.940360	Mean dependent var	0.251643
Sum squared resid	0.291791	Durbin-Watson stat	0.632204

Annex D. The Example of the Crises Factor as a Dummy Variable

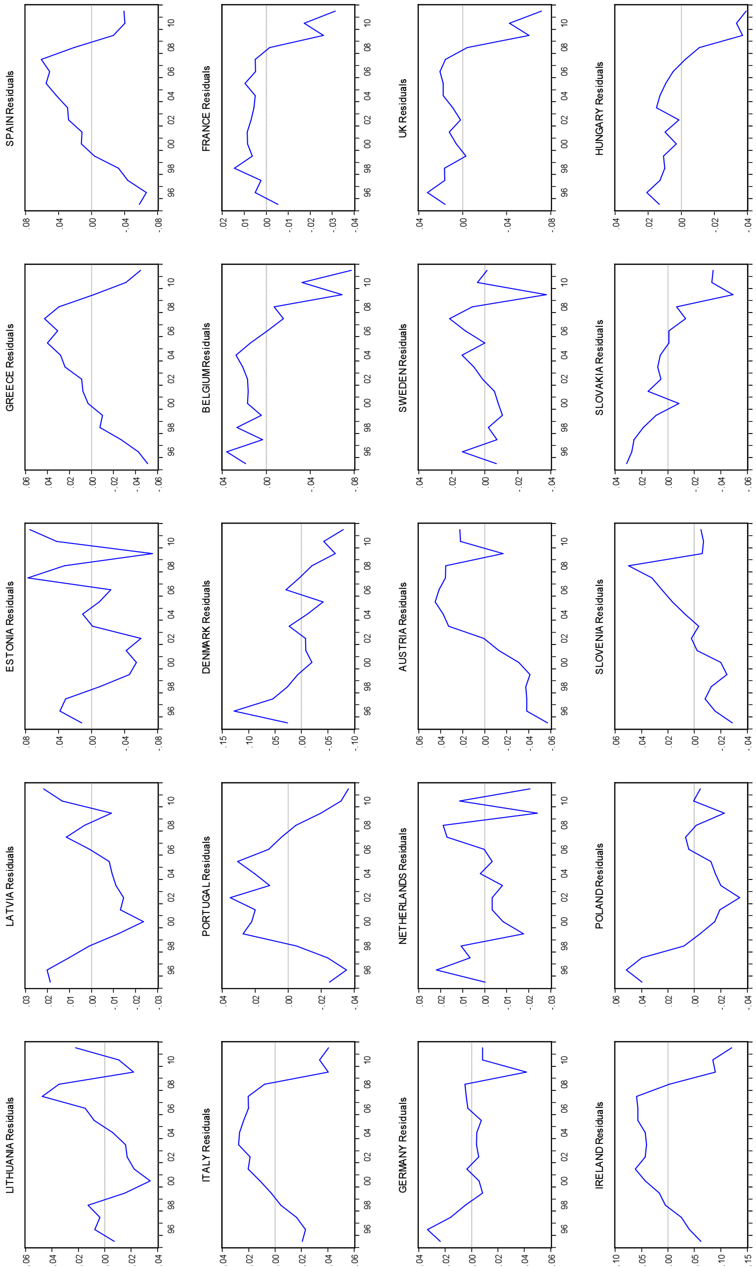
Table D.1. The example of the crises factor as a dummy variable

	NNGDP2_?	NNGDP2_?^2	RD_?	TAX1_?	SECT_?	ENERGTAX_?	CRIS	CRIS08
ESTONIA-1995	0,021374	0,000457	49,6	0,98	33	9,5	0	0
ESTONIA-1996	0,029008	0,000841	49,6	1,47	31,1	16	0	0
ESTONIA-1997	0,044275	0,00196	49,6	1,57	30,9	21,1	0	0
ESTONIA-1998	0,050382	0,002538	49,6	1,93	29	32,5	0	0
ESTONIA-1999	0,056489	0,003191	59,6	1,7	26,9	30,9	0	0
ESTONIA-2000	0,071756	0,005149	57,4	1,69	27,6	31,4	0	0
ESTONIA-2001	0,080916	0,006547	71,3	2,11	28,1	39,5	0	0
ESTONIA-2002	0,096183	0,009251	78,1	1,99	28,4	40,5	0	0
ESTONIA-2003	0,112977	0,012764	90,5	1,88	28,5	43,6	0	0
ESTONIA-2004	0,129771	0,016841	107,7	2,1	27,9	53,6	0	0
ESTONIA-2005	0,151145	0,022845	128,1	2,28	28,6	62,6	0	0
ESTONIA-2006	0,178626	0,031907	171,6	2,19	29,7	66,6	0	0
ESTONIA-2007	0,207634	0,043112	177,6	2,2	29,6	68,9	0	0
ESTONIA-2008	0,203053	0,041231	202,1	2,34	28,9	70,3	0	1
ESTONIA-2009	0,169466	0,028719	191,7	3	26,6	87	1	0
ESTONIA-2010	0,177099	0,031364	225,7	2,97	28,9	85,7	1	0
ESTONIA-2011	0,203053	0,041231	362,2	2,82	28,9	87,6	1	0
LATVIA-1995	0,010687	0,000114	24,2	1,07	30,3	17,4	0	0
LATVIA-1996	0,016794	0,000282	22,7	1,59	28,7	27,1	0	0
LATVIA-1997	0,025954	0,000674	22,9	2,06	29,4	34,6	0	0
LATVIA-1998	0,035115	0,001233	25,2	2,94	26,7	55,4	0	0
LATVIA-1999	0,039695	0,001576	24,1	2,44	24,6	47,9	0	0
LATVIA-2000	0,047328	0,00224	31,4	2,41	23,8	48,1	0	0
LATVIA-2001	0,056489	0,003191	31,4	2,19	23,3	42,3	0	0
LATVIA-2002	0,068702	0,00472	35,3	2,32	23	48,4	0	0
LATVIA-2003	0,079389	0,006303	34,4	2,5	22,4	55,3	0	0
LATVIA-2004	0,094656	0,00896	41,7	2,61	22,3	62,6	0	0
LATVIA-2005	0,109924	0,012083	62,4	2,68	21,8	71,4	0	0

LATVIA-2006	0,131298	0,017239	87,4	2,41	22	71,1	0	0
LATVIA-2007	0,158779	0,025211	82,4	2,08	23,3	70,8	0	0
LATVIA-2008	0,163359	0,026686	83,6	1,96	23,2	67,9	0	1
LATVIA-2009	0,134351	0,01805	51,6	2,33	20,6	67,3	1	0
LATVIA-2010	0,141985	0,02016	68,3	2,4	21,7	60,7	1	0
LATVIA-2011	0,164885	0,027187	85	2,46	21,7	67,4	1	0

Annex E. The Graphical Presentation of Residuals of the Reduced Form of the Environmental Kuznets Curve Model

Table E.1. The graphical presentation of residuals of the reduced of the environmental Kuznets curve model


SPAIN Residuals
FRANCE Residuals
UK Residuals
HUNGARY Residuals
GREECE Residuals
BELGIUM Residuals
SWEDEN Residuals
SLOVAKIA Residuals
ESTONIA Residuals
DENMARK Residuals
AUSTRIA Residuals
SLOVENIA Residuals
LATVIA Residuals
PORTUGAL Residuals
NETHERLANDS Residuals
POLAND Residuals
LITHUANIA Residuals
ITALY Residuals
GERMANY Residuals
IRELAND Residuals

Annex F. The Residuals of the Extended Model

Table F.1. The residuals of the extended model

	Res-LITHUANIA	Res-LATVIA	Res-ESTONIA	Res-GREECE	Res-SPAIN	Res-ITALY	Res-PORTUGAL	Res-DENMARK	Res-BELGIUM	Res-FRANCE	Res-GERMANY	Res-AUSTRIA	Res-NETHERLANDS	Res-SWEDEN	Res-UK	Res-IRELAND	Res-POLAND	Res-SLOVENIA	Res-SLOVAKIA	Res-HUNGARY
1995	-0,01	-0,01	0,01	-0,01	-0,02	0,01	0,00	0,02	0,02	0,00	0,03	-0,03	0,00	-0,01	-0,01	-0,02	0,02	-0,01	0,03	0,04
1996	0,02	0,00	0,04	-0,01	-0,03	0,01	-0,02	0,12	0,04	0,01	0,03	-0,02	0,01	0,02	0,00	0,00	0,04	-0,01	0,02	0,04
1997	0,00	-0,02	0,03	0,00	-0,02	0,01	-0,02	0,04	0,00	0,01	0,01	-0,02	0,01	-0,01	-0,01	0,00	0,03	-0,01	0,04	0,02
1998	0,01	-0,01	0,00	0,01	-0,01	0,01	-0,01	0,02	0,02	0,02	0,00	-0,02	0,01	0,00	0,00	0,00	0,00	-0,02	0,04	0,01
1999	-0,01	-0,01	-0,02	-0,01	0,01	0,01	0,02	0,01	0,00	0,01	-0,01	-0,03	-0,01	-0,02	-0,01	0,00	-0,01	-0,03	0,02	0,01
2000	-0,02	-0,02	-0,04	-0,01	0,01	0,01	-0,01	-0,02	0,00	0,00	0,00	-0,03	-0,01	-0,02	-0,01	0,01	-0,02	-0,03	0,00	0,00
2001	-0,02	-0,01	-0,04	-0,01	0,01	0,01	0,00	0,00	0,00	-0,01	0,01	-0,01	-0,01	-0,02	0,00	0,02	-0,01	-0,01	0,03	0,01
2002	-0,01	-0,01	-0,06	-0,01	0,02	0,00	0,02	0,00	0,00	0,00	0,01	0,00	-0,01	-0,01	0,00	0,00	-0,02	0,00	0,02	0,00
2003	-0,03	-0,01	0,00	0,01	0,02	0,02	0,01	0,03	0,01	0,00	0,01	0,03	-0,01	0,00	0,01	0,01	-0,01	-0,02	0,01	0,01
2004	-0,03	-0,01	0,01	0,01	0,02	0,01	0,02	-0,01	0,02	0,00	-0,01	0,03	0,00	0,00	0,02	0,02	-0,02	-0,01	0,00	0,00
2005	-0,02	0,00	-0,02	0,01	0,02	0,00	0,02	-0,06	0,01	0,00	-0,02	0,03	-0,01	-0,01	0,01	0,04	-0,01	0,00	-0,01	0,00
2006	-0,01	0,00	-0,05	-0,01	0,01	-0,01	0,00	0,00	-0,01	-0,01	-0,02	0,02	-0,01	0,00	0,01	0,03	0,00	0,00	-0,04	-0,01
2007	0,02	0,00	0,04	0,01	0,02	-0,01	-0,01	-0,03	-0,02	-0,01	-0,02	0,00	-0,01	0,00	0,01	0,03	0,00	0,01	-0,05	-0,02
2008	0,02	0,00	0,02	0,01	0,00	-0,02	0,00	-0,04	-0,01	-0,01	-0,01	0,01	0,01	0,01	0,00	0,01	0,00	0,04	-0,04	-0,01
2009	0,03	0,03	-0,05	0,01	-0,01	-0,02	0,01	-0,03	-0,03	0,00	-0,01	-0,01	0,01	0,01	0,00	-0,04	-0,01	0,05	-0,03	-0,02
2010	0,02	0,04	0,05	0,00	-0,02	-0,02	-0,01	-0,01	0,00	0,00	0,00	0,02	0,03	0,03	0,00	-0,04	0,01	0,03	-0,02	-0,03
2011	0,05	0,04	0,07	0,00	-0,02	-0,02	-0,01	-0,04	-0,06	0,00	0,00	0,02	0,00	0,02	-0,02	-0,07	0,00	0,02	-0,03	-0,04

Annex G. The Recalculation of the Model Covering 2007–2011 Period

Table G.1. The recalculation of the model covering 2007–2011 period

Dependent Variable: NNGGE_?
Method: Pooled EGLS (Cross-section weights)
Date: 02/21/14 Time: 15:23
Sample: 2007 2011
Included observations: 5
Cross-sections included: 20
Total pool (balanced) observations: 100
Linear estimation after one-step weighting matrix
White cross-section standard errors & covariance (no d.f. correction)
WARNING: estimated coefficient covariance matrix is of reduced rank

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.051922	0.031318	-1.657894	0.1017
NNGDP2_?	1.087831	0.044341	24.53343	0.0000
NNGDP2_?^2	-1.231005	0.057492	-21.41164	0.0000
RD_?	0.000105	2.75E-05	3.819587	0.0003
TAX1_?	0.049993	0.004398	11.36623	0.0000
ENERGTAX_?	-0.001051	0.000104	-10.10878	0.0000
SECT_?	0.002735	0.000573	4.774415	0.0000
CRIS08	-0.010765	0.000732	-14.70867	0.0000
CRIS	-0.028108	0.002397	-11.72409	0.0000
Fixed Effects (Cross)				
LITHUANIA--C	-0.074376			
LATVIA--C	-0.135420			
ESTONIA--C	0.185117			
GREECE--C	0.103164			
SPAIN--C	-0.047315			
ITALY--C	0.008548			
PORTUGAL--C	-0.073036			
DENMARK--C	0.067400			
BELGIUM--C	0.044107			
FRANCE--C	-0.041631			
GERMANY--C	0.064584			
NETHERLANDS--C	0.035767			
AUSTRIA--C	-0.060341			
SWEDEN--C	-0.140742			
UK--C	0.100872			
IRELAND--C	0.143355			
POLAND--C	0.051963			
SLOVENIA--C	-0.031069			
SLOVAKIA--C	-0.076233			
HUNGARY--C	-0.124713			

Effects Specification			
Cross-section fixed (dummy variables)			
Weighted Statistics			
R-squared	0.991774	Mean dependent var	0.393016
Adjusted R-squared	0.988689	S.D. dependent var	0.275775
S.E. of regression	0.015708	Sum squared resid	0.017765
F-statistic	321.5011	Durbin-Watson stat	1.946829
Prob(F-statistic)	0.000000		
Unweighted Statistics			
R-squared	0.981724	Mean dependent var	0.225859
Sum squared resid	0.020357	Durbin-Watson stat	1.868438

Annex H. Possible Scenarios of Countries' Development in the Period of 2014–2024

Table H. 1. The change in the percentage of greenhouse gas emissions based on three modelled scenarios

	The GDP increase of about 2% per year	The GDP increase of about 2% per year and energy taxes increase of about 1% per year	The GDP increase of about 2% per year and industrial sectors decline of about 1% per year
Lithuania	6,7	1,4	-12,9
Latvia	27,8	12,2	-20,6
Estonia	1,1	-0,2	-2,9
Greece	0,1	-3,8	-4,0
Spain	-6,6	-10,9	-15,5
Italy	-7,2	-14,0	-14,8
Portugal	0,8	-6,1	-10,2
Denmark	-14,2	-21,1	-18,7
Belgium	-9,7	-11,6	-13,4
France	-14,9	-21,9	-22,4
Germany	-12,2	-16,3	-17,7
The Netherlands	-14,9	-18,8	-19,4
Austria	-20,7	-25,0	-28,5
Sweden	-52,1	-70,2	-72,4
The United Kingdom	-10,7	-18,4	-16,4
Ireland	-11,0	-13,6	-15,3
Poland	2,3	0,1	-4,6
Slovenia	-1,1	-6,0	-10,0
Hungary	3,8	0,7	-8,4
Slovakia	1,3	-0,1	-8,3

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Doctoral Dissertation
Social Sciences,
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EKONOMIKOS AUGIMO ĮTAKOS ŠILTNAMIO EFEKTĄ
SUKELIANČIŲ DUJŲ EMISIJAI VERTINIMAS

Daktaro disertacija
Socialiniai mokslai,
Ekonomika (04S)

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