Economic Growth and the Environmental Degradation: the Review of the Scientific Research

Giedrė Lapinskienė[1], **Kęstutis Peleckis** [2], **Valentina Peleckienė**[3]

[1,2,3]*Vilnius Gediminas Technical University, Saulėtekio ave. 11, LT-10223 Vilnius, Lithuania*
Emails: [1]*giedre.lapinskiene@vgtu.lt* (corresponding author*),* [2]*kestutis.peleckis@vgtu.lt,*
[3]*valentina.peleckiene @vgtu.lt*

Abstract

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. 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 environmental Kuznets curve indicates that, at the early stages of economic growth, pollution increases with the growing use of resources, but when a certain level of income per capita is reached, the trend reverses so that, at a higher development stage, further economic growth leads to the improvement of the environment. The aim of this paper is to describe the evolution of the environmental Kuznets curve, starting from its roots till nowadays, to summarise and systemise the results of empirical studies of the relationship between the air quality indicators (due to global climate change) and economic growth. In the article the most influential theories of the environmental economics are described in order to highlight the strong environmental approach. The article may be useful for scientists and policy makers, 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.

Keywords: environment, environmental Kuznets curve, economic growth, greenhouse gases.

JEL Classification: Q56; C33

Introduction

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 18th 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 "The Limits to Growth", the environmental quality has been considered as another one prerequisite for economic growth (Meadows *et. al* 1972). 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. The environmental problems based on their relationship to economic growth could be generally grouped into three approaches. 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 environmental Kuznets curve (further 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. In the scientific world, 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; Randers 2012).
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; Galeotti *et al.*2008; Franklin and Ruth 2012; Wang 2013).

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. The third approach named the environmental Kuznets curve (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.

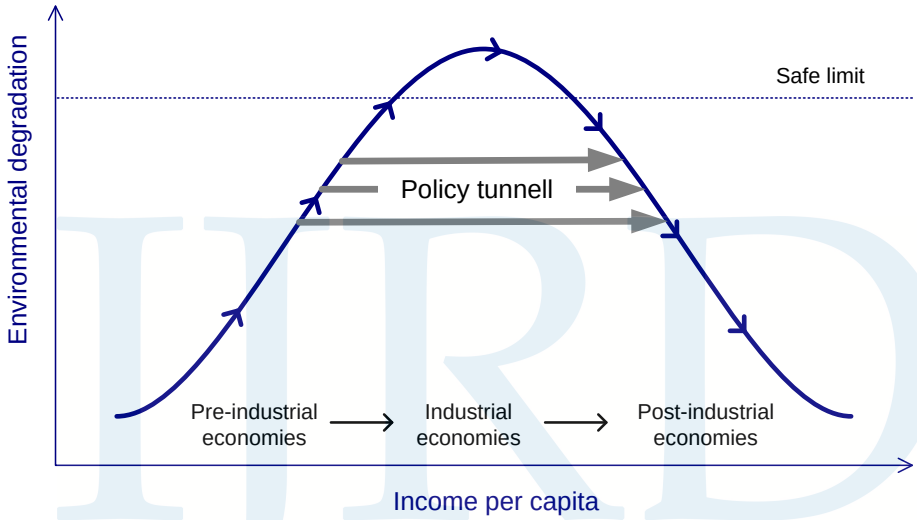

Fig. 1. The Environmental-growth relationship, the EKC approach
Source: R. Čiegis „Gamtos išteklių ir aplinkos ekonomika" (Natural Resources and Environmental Economics) p.147

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 *et. al* (2008), 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, the EKC 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.

The aim of this paper is to describe the evolution of the environmental Kuznets curve, starting from its roots till nowadays, to summarise and systemise the results of empirical studies. The article may be useful for scientists

and policy makers, 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 paper has the following structure. In Section 1, the most influential theories of the environmental economics are described to highlight the environmental aspect. In Section 2,3,4 a thorough analysis of the EKC evolution since its root till our days is presented. The last section summarizes the results, providing the concluding remarks and defining possible areas for further research.

1. The Interrelation of Economic Growth and the Indicators of Environmental Degradation – Environmental Approach

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. 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 (Randers 2012).

Environmentalists and other researchers aiming at preservation of the natural environment feel huge hopelessness as the behavioural patterns of human beings, despite the sustainable development 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.

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.

2. 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. 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 (1994) 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.

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.

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.

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 critical remarks of Stern *et al.* (1996) based on the previous studies found in the article 'Economic Growth and Environmental Degradation: The environmental Kuznets curve and Sustainable Development' are presented below. 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.

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.

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

Further analysis of the empirical studies will be more concentrated on the relationship between the air quality, which captures CO_2 emission, and economic growth, due to global climate change.

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).

In 1998, Unruh and Moomaw 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).

In 1999, 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).

Two influential critical articles written by Stern and Dinda are presented below. The authors summarized the investigations performed in the EKC area.

Based on the reviewed studies, Stern (2004) concluded, that based on the analysis of the many studies, 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.
5. 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 summarised the studies of EKC of the 20th 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 greenhouse gases (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.

4. 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). Analysing the literature on the EKC hypothesis, the author pointed out the aspects that were not widely cited in other literature. He highlighted that famous EKC researchers, such as Grossman and Krueger, had not cited the famous books, such as “The Limits to Growth” and “The Population Bomb” (described above). 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, he 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.

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.

Galeotti *et al.* (2006), 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.

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.

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 of publication	Received functional form	Sample and time period	Model
Shafik and Bandyopadhyay	1992	Monotonically rising	149 countries, 1960-90	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, 1951-86	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), 1962-91	Generic flexible functional form allowing a potentially non-linear non-monotonic relationship.
Unruh and Moomaw	1998	EKC	16 countries, 1950-92	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 1971-98	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
Franklin and Ruth	2012	EKC, but show a "rebound effect", suggesting continued upward trend.	United States , 1800-2000	Non-linear functional forms, which in the statistical literature were known as Gamma-Weibull functions
Fosten *et al.*	2012	EKC	United Kingdom, 1830 to 2003 –200	Log-squared regression.
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.
Wang	2013	EKC	138 countries,1971-2007	Standard cubic log-linear.
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.

Lapinskienė *et. al*	2014	EKC	Twenty seven member-states of the European Union as well as Switzerland and Norway in the period 1995-2010.	Panel data cubic regression.

Source: made by authors

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 results can be divided into several groups including many approvals of the inverted U, some increasing trends and some other tendencies. The interest area varies for different countries, regions and, sometimes, cities. 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), and b) panel data techniques for the analysis of several regions (Lapinskienė *et. al* 2014, 2013; Hamit-Haggar 2012; Culas 2012; 2009; Huang *et al.* 2008). Some studies support the EKC hypothesis, while others find a monotonically rising trend.

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. 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: scale of economic activity; 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.

Note that even if the EKC has been proved for emissions per capita, pollution still remains a problem for the following reasons:

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

Conclusion

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.

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.

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, are used to empirically check their statistically significant impact on the environmental indicator.

References

Ahmad, R. M. Al Sayed; Siok Kun Sek 2013. Environmental Kuznets Curve: Evidences from Developed and Developing Economies, *Applied Mathematical Sciences* 7(22): 1081–1092.

Beckerman, W. 1992. Economic Growth and the Environment: Whose Growth? Whose Environment?, *World Development* 20: 481–496.

Carson, R.T. 2010. The Environmental Kuznets Curve: Seeking Empirical Regularity and Theoretical Structure, *Environ Econ Policy Winter* (4): 3 - 23. http://dx.doi.org/10.1093/reep/rep021

Čiegis, R. 2009. Gamtos išteklių ir aplinkos ekonomika (Natural Resources and Environmental Economics), Klaipėdos universiteto leidykla, Klaipėda 772 p.

Čiegis, R.; Štreimikienė, D.; Zavadskas, E. 2008. The Use of Environmental Kuznets Curve: Environmental and Economic Implications, Environment and Pollution 33(2/3): 313–335.

Cole, M. A.; Neumayer, E. 2004. Examining the Impact of Demographic Factors on Air Pollution, Population and Environment 26(1): 5–21.

Culas, R. 2012. REDD and Forest Transition: Tunnelling through the Environmental Kuznets Curve, *Ecological Economics* 79: 44–51.

Dasgupta, P.; Maler, K. G. 1994. Poverty, Institutions, and the Environmental-resource Base. World Bank Environment paper number 9. Washington, D.C. Backgroung paper [online], [cited 5 March 2014]. Available on the Internehttp://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/1994/03/01/000009265_3970702134014/Rendered/PDF/multi_page.pdf#page=1&zoom=auto,-98,798
Dinda, S. 2004. Environmental Kuznets Curve Hypothesis: a Survey, *Ecological Economics*, 49: 431–455. http://dx.doi.org/10.1016/j.ecolecon.2004.02.011

Ehrlich, P. R. 1968. *The population bomb*. Ballantine books. New York. 25 p.

Esteve, V.; Tamarit, C. 2012. Is There an Environmental Kuznets Curve for Spain? Fresh Evidence from Old Data, *Economic Modelling* 29: 2696-2703. http://dx.doi.org/10.1007/s10640-014-9871-z

Fodha, M.; Zaghdoud, O. 2010. Economic growth and pollutant emissions in Tunisia: An empirical analysis of the environmental Kuznets curve, Energy Policy 38(2): 1150–1156. http://dx.doi.org/10.1016/j.enpol.2009.11.002

Fosten, J.; Morley B.; Taylor, T. 2012. Dynamic misspecification in the environmental Kuznets curve: Evidence from CO_2 and SO_2 emissions in the United Kingdom, Ecological Economics 76: 25–33. http://dx.doi.org/10.1016/j.ecolecon.2012.01.023

Franklin, R. S.; Ruth, M. 2012. Growing up and cleaning up: the environmental Kuznets curve, *Applied Geography* 32: 29–39. http://dx.doi.org/10.1016/j.apgeog.2010.10.014

Fujii, H., Managi, S. 2013. Which industry is greener? An empirical study of nine industries in OECD countries, *Energy Policy*, 57:381-388. . [Online], [cited 10 May 2012]. Available on the Internet: http://mpra.ub.uni-muenchen.de/id/eprint/44229

Galeotti, M, Alessandro, Lanza 1999. Richer and cleaner? A study on carbon dioxide emissions in developing countries, *Energy Policy* 27(10):565-573.

Galeotti, M.; Lanza, A.; Pauli, F. 2006. Reassessing the environmental Kuznets curve for CO2 emissions: A robustness exercise, Ecological Economics 57(1):152-163 http://dx.doi.org/10.1016/j.ecolecon.2005.03.031

Grossman, G. M.; Krueger, A. B. 1991. Environmental impact of a North American free trade agreement, Working Paper 3194. Cambridge, MA: National Bureau of Economic Research. [Online], [cited 10 July 2012]. Available on the Internet: http://www.nber.org/papers/w3914.pdf

Grossman, G. M.; Krueger, A. B. 1995. Economic growth and the environment, Quarterly Journal of Economics 110:353–377. [Online], [cited 15 July 2012]. Available on the Internet: https://groups.nceas.ucsb.edu/sustainability-science/2010%20weekly-sessions/session-2-09.20.2010-sustainability-science-and-sustainable-development/supplemental-readings-from-umn-group/Grossman1995.pdf/view

Hamit-Haggar, M. 2012. Greenhouse gas emissions, energy consumption and economic growth: A panel cointegration analysis from Canadian industrial sector perspective, *Energy Economics* 34: 358–364. http://dx.doi.org/10.1016/j.eneco.2011.06.005

He, J., Wang, H. 2012. Economic structure, development policy and environmental quality: an empirical analysis of environmental Kuznets curves with Chinese municipal data, *Ecological Economics*, 76: 49-59. http://dx.doi.org/10.1016/j.ecolecon.2012.01.014

He, J.; Richard, P. 2010. Environmental Kuznets curve for CO^2 in Canada, *Ecological Economics* 69(5): 1083–1093. http://dx.doi.org/10.1016/j.ecolecon.2009.11.030

Holtz-Eakin, D.; Selden, T.M. 1995. Stoking the fires? CO^2 emissions and economic growth, *Public Economics* 57: 85–101.

Huang, W. M.; Lee, G. W. M.; Wu, C. 2008. GHG emissions, GDP growth and the Kyoto Protocol: A revisit of Environmental Kuznets Curve hypothesis, *Energy Policy* 36(1): 239–247. http://dx.doi.org/10.1016/j.enpol.2007.08.035

Lapinskienė, G.; Tvaronavičienė, M.; Vaitkus, P. 2014. The emissions of greenhouse gases and economic growth – the evidence of the presence of the environmental Kuznets curve in the European Union countries, *Technological and Economic Development of Economy* 20(1): 65–78. http://dx.doi.org/10.3846/20294913.2014.881434

Lapinskienė, G.; Tvaronavičienė, M.; Vaitkus, P. 2013. Analysis of the validity of environmental Kuznets curve for the Baltic States, *Environmental and Climate Technologies* 12: 41–46. http://dx.doi.org/10.2478/rtuect-2013-0015

Liao, H.; Cao, H. 2013. How does carbon dioxide emission change with the economic development? Statistical experiences from 132 countries, *Global Environmental Change* 23: 1073–1082. http://dx.doi.org/10.1016/j.gloenvcha.2013.06.006

Malthus, T.1798. An Essay on the Principle of Population. 134p. [Online], [cited 1 July 2012]. Available on the Internet: http://www.esp.org/books/malthus/population/malthus.pdf

Meadows, D., Randers, J. Meadows, D. 2004. *Limits to Growth: The 30-Year Update*, USA, Chelsea Green publishing Company. 368 p.

Meadows, D.H., Meadows, D. L., Randers, J., Behrens, W. 1972. *Limits to Growth: A report for the Club of Rome's Project on the Predicament of Mankind*. New York: Universe Books. 211 p.

Panayotou, T. 1997. Demystifying the environmental Kuznets curve: turning black box into a policy tool, *Environment and Development Economics* 2: 465–484.

Panayotou, T. 2003. Economic growth and the environment. *Economic survey of Europe*. UNECE, 2. [Online], [cited 12 May 2013] Available on the Internet: http://www.unece.org/fileadmin/DAM/ead/pub/032/032_c2.pdf

Randers, J. 2012. *A global forecast for the next forty years 2052*. Chelsea green publishing white river junction, Vermont. 392p.

Saboori, B.; Sulaiman, J.; Mohd, S. 2012. Economic growth and CO2 emissions in Malaysia: A cointegration analysis of the Environmental Kuznets Curve, *Energy Policy* 51: 184–191. http://dx.doi.org/10.1016/j.enpol.2012.08.065

Selden, T. M.; Song, D. 1994. Environmental quality and development: Is there a Kuznets curve for air pollution emissions? *Environmental Economics and Management* 27: 147–162

Shafik, N.; Bandyopadhyay, S. 1992. Economic growth and Environment Quality: Time Series and Cross-Country Evidence, Background Paper for the World Development Report, The World Bank, Washington DC. [Online], [cited 1 May 2013] Available on the Internet: http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/1992/06/01/000009265_3961003013329/Rendered/PDF/multi_page.pdf

Stern, D. I. 1998. Progress on the environmental Kuznets curve? *Environ. Dev. Econ*. 3: 173–196.

Stern, D. I. 2004. Rise and fall of the Environmental Kuznets Curve, *World Development* 32(8):1419–1439. http://dx.doi:10.1016/j.worlddev.2004.03.004

Tsurumi, T.; Managi, S. 2010. Decomposition of the environmental Kuznets curve: scale, technique, and composition effects, *Environmental Economics and Policy Studies* 11: 19–36. http://dx.doi:10.1016/j.jeem.2009.04.008

Unruh, G.C, Moomaw W.R. 1998. An alternative analysis of apparent EKC-type transitions, *Ecological Economics* 25: 221–229.

Wang, K.M. 2013. The relationship between carbon dioxide emissions and economic growth: quantile panel-type analysis, *Qual Quant* 47:1337-1366. http://dx.doi: 10.1007/s11135-011-9594-y