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THE RELATIONSHIP BETWEEN GREENHOUSES GAS EMISSIONS AND ECONOMIC GROWTH: POSSIBLE CAUSES OF ENVIRONMENTAL KUZNETS CURVE PATTERNS

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ABSTRACT

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 greenhouse gas emissions (GHG) emissions at the level, which could help to prevent dangerous anthropogenic interference with the climate system. 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.

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

JEL Classification: Q56

INTRODUCTION

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

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Volume:02, Issue:04

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 (Casper 2010). Much of economic activity and results in human−induced climate change, which should be corrected through institutional, market or policy intervention. 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).

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. (Grossman, Kreuger 1993; Selden, Song 1994; Panayotou 1997; 2003; Galeotti *et al.*2008; Franklin and Ruth 2012; Wang 2013).

The aim of this paper is to summarise and systemise the results of empirical studies of the relationship between greenhouse gas emissions or carbon dioxide and economic growth and to highlight possible causes of environmental Kuznets curve (EKC) patterns. 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, a thorough analysis of the EKC evolution of the studies conducted in 1996-2005 is presented. In Section 2, the evaluation of the studies conducted in 2005 and later is analyse. The last section provides the concluding remarks.

1. 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

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Volume:02, Issue:04

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

ISSN: 2455-8834

Volume:02, Issue:04

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

ISSN: 2455-8834

Volume:02, Issue:04

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).

ISSN: 2455-8834

Volume:02, Issue:04

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

ISSN: 2455-8834
Volume:02, Issue:04

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

ISSN: 2455-8834

Volume:02, Issue:04

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.

2. 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". 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

ISSN: 2455-8834

Volume:02, Issue:04

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

ISSN: 2455-8834

Volume:02, Issue:04

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

ISSN: 2455-8834
Volume:02, Issue:04

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

ISSN: 2455-8834

Volume:02, Issue:04

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
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	30 OECD countries, 1960–2003	Two models - quadratic and quadratic in the natural logarithms

ISSN: 2455-8834

Volume:02, Issue:04

		second group - a monotonically increasing trend, the third group - other trends which are too wide to interpret.		
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

ISSN: 2455-8834

Volume:02, Issue:04

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

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 interest in the EKC studies 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.

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

ISSN: 2455-8834

Volume:02, Issue:04

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.

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.

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

Casper, J.K. 2010. *Climate Management– Solving the Problem*. New York. 356 p.

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

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

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

ISSN: 2455-8834

Volume:02, Issue:04

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

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

ISSN: 2455-8834

Volume:02, Issue:04

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

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 07 April 2017] Available on the Internet: http://www.unece.org/fileadmin/DAM/ead/pub/032/032_c2.pdf

Roberts, J. T.; Grims, P. E. 1997. Carbon intensity and economic development 1962-91: a brief exploration of the Environmental Kuznets Curve. *World Development* 25: 191–198.

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.

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

