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THE ANALYSIS OF THE VALIDITY OF ENVIRONMENTAL KUZNETS CURVE OF THE EU MEMBER STATES

Giedrė Lapinskienė[1], Marijus Radavičius[2]

[1]*Vilnius Gediminas Technical University, Faculty of Business Management, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania*
Email: giedre.lapinskiene@dok.vgtu.lt

[2]*Vilnius Gediminas Technical University, Faculty of Fundamental Sciences, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania*
Email: marijausr@gmail.com

Abstract. The paper analyses a common Environmental Kuznets Curve (EKC) relationship between greenhouse gases (GHG) and gross domestic product (GDP). The EKC 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. In the article the validity of the reduced-form EKC for twenty European Union states for the period 1995–2011 is determined. The fixed effect panel model is used. The research results may be useful for the climate change policy design.

Keywords: greenhouse gases, Environmental Kuznets Curve, European Union, climate change, panel model.

JEL classification: Q51, C33.

1. Introduction

For a long time, humans have believed that the planet is capable to restore the damage made by their activities. New inventions at the end of the18th century led to the industrial revolution, and over the period of about 150 years, the natural processes on the planet were broken. Since the 1970s, when the Club of Rome put forth the theory of "Limits to growth", the environmental quality has been considered as a new prerequisite for economic growth (Meadows *et al.* 1972).

The problem of greenhouse gas emissions from human activities is highlighted as one of the main environmental issues in today's world, which requires the immediate reaction and behavioural changes. According to Nicholas Stern, emissions have been strongly correlated with GDP per head across time and countries, and without action to combat climate change, atmospheric concentrations of greenhouse gases will continue to rise (Stern 2009).

The question how the economic growth harms the environment and how to sustain economic growth without running into the potentially irreversible process of environmental destruction has been widely discussed by environmental economists. For some decades in the centre of this discussion the so-called Environmental Kuznets Curve (EKC) (after the publication of seminal works of Grossman and Krueger (Grossman, Krueger 1991, 1995)). Environmental economists had built on this concept by hypothesizing the same type of relationship between the level of environmental degradation and income growth. The relationship between various indicators of environmental degradation (air pollutants, e.g. CO_2, SO_2, GHG, water pollutants, waste and other specific environmental pollutants) and economic development generally expressed as income per capita or GDP, was analysed, and it was proposed that this relationship could have the inverted-U form. This indicates that, at the early stages of economic growth, the environmental degradation and pollution are increasing, but beyond some level of income, the trend reverses so that the economic growth leads to the environmental improvement. Since then, the EKC relationship has been widely analysed by scientists, considering various environmental indicators, countries and regions.

The present investigation aims to evaluate the relationship between GHG as the main variable of climate change and GDP based on the EKC approach. The data for the full sample chosen are the panel data for the period 1995–2011 in twenty European countries as the region representing similar development levels, geographic areas and having some similar EKC patterns. The specific objectives of this paper are as follows:

- to review and assess the available literature on EKC;
- to perform the reduced-form EKC estimation of the fixed effect panel model for the whole sample.

The hypothesis is as follows: can the EKC form be supported by the analysis of the impact of GDP growth on the GHG in the European Union in the period of 1995–2011?

The novelty of the paper is associated with the considered sample of different countries of the same economic area and the tested period.

The paper has the following structure. Sections 2 and 3 provide some important theoretical and econometrical issues based on the concepts considered. Section 4 describes the main findings of the research. The last section summarizes the results, providing the concluding remarks and defining possible areas for further research.

2. The review of the literature

The relationship between the economic growth and environmental quality presented by the inverted-U has been widely studied since 1990s. Many researchers have agreed that Grossman, G. M. and Krueger, A. B. were the scientists who boosted the research in 1990. This concept was popularized through the 1992 World Bank Development, which used some additional environmental indicators and included more countries (Shafik & Bandyopadhyay 1992). Dasgupta P. and Maler K. were the scientists who named the relationship between the income per capita and industrial pollution the Environmental Kuznets Curve (Čiegis 2009). At the end of the 20^{th} century the researchers analysing the EKC, were Selden and Song, Grossman and Krueger, Shafik and Bandyopadhyay, Holtz-Eakin and Selden, Selden and Song as well as Panayotou, and they can be referred to the classics of the EKC (Grossman & Krueger 1991, 1995; Shafik & Bandyopadhyay 1992; Selden & Song 1994; Holtz-Eakin & Selden 1995; Panayotou 1995). The famous critical observations were presented by Stern, Dinda, Carson (Stern *et al.* 1996; Dinda 2004; Carson 2010).

Further analysis of the empirical studies will be centered on the relationship between the air quality, which captures CO_2 (as the main gas of GHG) emission, and economic growth. The relationship the between carbon dioxide variable and economic growth was first analysed in the World Bank study. The World Bank analysis of cross-country data from 1980 to 1990 revealed that the additional amount of carbon dioxide released into the atmosphere due to human activities between 1980 and 1989 came principally from fossil fuels. The researchers emphasized that future trends in GHG concentrations would depend on a number of criteria and economic growth would be one of them. The results of the research showed the increasing trends in the relationship between carbon dioxide and GDP (Shafik, Bandyopadhyay 1992).

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 their income. The researchers used the environmental indicator called 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 emission per unit of GDP across the period of 30 years and tracked the changes in the chosen groups of the countries. The authors thought that the existence of the inverted U – curve for CO_2 emission intensity would suggest that the pollution reduction might 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. Hence, they proved the existence of the inverted – U relationship. Examining the path of National Carbon Intensity in different groups of countries for the chosen 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 CO2/GDP in 1982 was due to the efficiency improvements in the rich countries and worse performance in the poor and middle – income nations.

In an effort to evaluate whether income was the determining variable, G. C. Unruh and W. R. Moomaw (1998) 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 a multiple or even infinite number of solutions. The authors generated phase diagrams for sixteen countries in the ORNL CO_2 data set and inspected them for evidence of attractors. 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, between 1970–1980, 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. (Unruh, Moomaw 1998).

The researchers used a panel data model for 110 countries to estimate the relationship between CO_2 and GDP and to forecast emissions in the period between 1971 and 1996. The sample covered 88% of the CO_2 emission 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 feature 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 co-operation (Galeotti, Lanza 1999).

Galeotti *et al*. 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 estimation based on two different data sources (panel data) was made by using a standard cubic log-linear EKC relationship for the comparable number of the countries and the period. The obtained coefficients were rather stable across two data sets. Some differences were noticed with the non-OECD group. The EKC was observed for the OECD countries. The non-OECD sample was characterized by the increasing slightly concave relationship. For the second check of robustness, they proposed an alternative functional form with some appealing features. They employed a three-parameter Weibull function. Graphically presented results demonstrated a bell-shaped curve with reasonable turning points for the group of the OECD countries and a less pronounced curve without reasonable turning points for the non- OECD countries (Galeotti *et al.* 2006).

V. Esteve and C 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 the 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 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 (Esteve, Tamarit 2012).

The authors contributed to the area of 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 (Franklin, Ruth 2012).

One stream of the 21th studies of the EKC covers the analyses in different industries in OECD countries (Fujii, Managi 2013). Hidemichi Fujii, Shunsuke Managi 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 proportion-ally 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 in-dustry in GDP (the share of the industrial sector's value added in the total GDP). It was sup-posed that these control variables would positively im-pact 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. CO_2 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 (Fujii, Managi 2013).

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 examined the environ-mental 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 of 1960–2003. The authors classified 30 OECD countries into three groups. The dependent variables covered the log of CO2, while independent variables covered the real log of GDP per capita. The results imply that eco-nomic 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 inter-pret. Their results suggested that economic growth is not sufficient to decrease CO_2 emissions (Tsurumi, Managi 2010).

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 indica-tors which demonstrated the existence of the EKC. They showed that the developed countries had higher turning points than the developing countries and allowed the authors to conclude that a higher economic growth might produce different effects on the environmental quality in different econo-mies (Ahmad *et al*. 2013).

Their studies emphasize the specific behav-iour of the EKC in their countries compared to that in the developed world. For example, Huang et al 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 equitations. The research revealed that the economic development and GHG in the econ-omies 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 empha-sized that, to achieve the Kyoto Protocol objec-tives, the parties should implement the policies, which specifically limit GHG with the aim of re-tarding the climate change (Huang *et al.* 2008).

Wang performed a panel data analysis of car-bon dioxide emissions and economic growth in 138 countries in the period of 1971-2010. The chosen sample was divided into five quintiles ac-cording 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 in-creasing 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 rela-tionship, 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 (Wang 2011).

In Table 1, summarized empirical findings of studies, where carbon dioxide or GHG is considered to be a dependable variable of the environmental quality, are presented.

Table 1. Summarized empirical findings (source: compiled by authors)

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 equation regression cross-country regression
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
Huang *et al*.	2008	No clear trend in developed countries, 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 too wide to interpret.	30 OECD countries, 1960–2003	Two models - quadratic and quadratic in the natural logarithms
Wang	2011	EKC	138 countries, 1971-2007	standard cubic log-linear
Franklin and Ruth	2012	EKC, but show a "rebound effect", suggesting continued upward trend.	United States, 1800–2000	Non-linear functional form, which in the statistical literature were known as Gamma-Weibull functions
Franklin and Ruth	2012	EKC	U.S.	Panel regression
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
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 regression

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

– 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.

The main idea of the reduced EKC model is the direct analysis of the economic growth impact on various environmental indicators.

3. The data used for the analysis

In this analysis, twenty European states were considered to determine the EKC relationship between GHG and GDP. Bulgaria, Romania and Croatia were not included, as these countries joined the European Union only recently (2007 and 2013), and it is a short period for the implementation of the European Union policy in these states. Luxemburg, Cyprus and Malta were not analysed either because their population is less than 1 mln., which may distort calculations of per capita terms. It is considered that the development path of these countries would be different from the whole sample. Finland and Czech Republic were excluded after calculating separate multiple regressions for 22 European countries because the cubic models of these two countries did not show the statistical significance (Lapinskienė *et al.* 2014). The considered countries are presented in the table below and described by providing the information about their development stage. The information about the stage of development of each country is taken from the World Competitiveness Report (2011-2012) and presented in Table 2.

Table 2. Stages of countries' development according to WEF (Source: World Economic Forum. The Global Competitiveness Report 2011–2012)

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

The data for the full sample chosen is available in the Eurostat database for the period of 1995–2011.

In this research, GHG represents a dependable variable of the environmental characteristics. This variable was identified and described in the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol and the Decision 280/2004/EC and presented in the Eurostat database. The key elements of the emitted greenhouse gases were defined in the Kyoto basket protocol as follows: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride (Eurostat 2013). Carbon dioxide is mainly produced by burning fossil fuels, in particular, for electricity generation and operation of transport and industry. Changes in the level of CO_2 are also caused by deforestation and declining algae in the water. Generation of methane is associated with human activities, such as gas mining and burning, animal husbandry, rice cultivation and dumps. Nitrous oxide is obtained in producing various nitrogen fertilizers, fuel burning and chemical industry. F-gases (hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) are gases generated only by human activities, because there are no natural sources of these gases in the environment. The amount of greenhouse gases in every country is estimated by combining information about human activity with a coefficient quantifying the emissions from that activity. Such coefficients are termed 'emission factors', and may be used as follows:

Emissions = activity data * emissions factor (Eurostat Statistical Book 2010).

GDP expressed in purchasing power-parity is specifically used in this research in order to minimise the potential differences in prices between the countries, which may be at different stages of development. Usually, various GDP expressions are taken by researchers as the main independent variables.

4. The methodology of analysis

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

– data normalisation;
– dummy variables;
– fixed effect panel data model.

In order to perform the analysis, the data of various countries over a certain time period are needed. In econometrics, this kind of the data structure is referred to as panel data. A panel data set consists of a time series for each cross-sectional member in the data set. The data set is associated with the same time periods for each cross section observation, and therefore is defined as a balanced panel. The research area covers the history of state processes. When pooling data from different countries into a single model, it is important to refer to the differences in some variables. To have the comparable data, the data sets for the analysis are chosen from Eurostat, which automatically ensures the same or very similar methodology, and covers the EU countries. Only the countries with complete data sets were chosen for the analysis to avoid possible data gaps. In order to avoid potential distortions and/or very small beta coefficients, the data for GHG and GDP were normalised to vary between 0 and 1, when the smallest value of the whole EU sample is equal to 0, and the largest value is equal to 1 (the formula is given below). At the same time, this facilitates the comparison of the results, as for example 0.5 equals to the average EU level:

$$(GDP_{it} - \min GDP_{EU}) / (\max GDP_{EU} - \min GDP_{EU}). \quad (1)$$

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

According to Matyas, "the simplest and most intuitive way to account for individual and/or time differences in behaviour, in the context of a panel data regression problem, is to assume that some of the regression coefficients are allowed to vary across individual and/or through time. The regression coefficients are unknown, but fixed parameters. When these are allowed to vary in one or two dimensions, we have a fixed effect model (Matyas 2008). In order to eliminate the variations of the countries' GHG level, the intercept for each country is considered as fixed effect.

The selected model is given by eq (2):

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

where:

GHG_{it} – is a dependent variable for country *i* in time *t*;

GDP_{it} – is an independent variable for country *i* in time t;

β_{it} – denotes the regression coefficients;

μ_i – is the cross-section specific effect;

ε_{it} – is an error term.

For the panel model estimation, the Eviews software was used. Eviews is a program for statistical and econometric analysis, and forecasting. The pooled EGLS (cross-section weight) method was chosen for the estimation of regression coefficients.

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

1. R^2 and *Adjusted* R^2;
2. P-values of Fisher and Student tests;
3. Residuals.

The model was validated by considering the adjusted R^2 and p-value as the values, indicating the fitness of the regression. The higher the R^2 value, the better the explanatory power for the curve fitting. Specifically, the P-value was used to examine the statistical significance of the effect of the independent variables on the dependent variable. In this EKC estimation, P-value was used to determine the significance of GDP, GDP squared and GDP cubic. When the P-value is lower than 0.05, it indicates that this coefficient has a statistically significant explanatory power with the probability of 95%.

5. Estimation results

The data on the selected countries for the period 1995–2011 were pooled together to estimate the reduced EKC for the whole sample for the hypothesis. The total pool balanced observations cover 340 points, consisting of 17 years of data for 20 countries. The reduced form EKC was estimated, using both cubic and quadratic functions, but coefficients in cubic estimation did not show a strong statistical significance (P-values were higher then 0.05). The reason for this result can be seen from the data plot in Figure 1 (using MS Excel), where quadratic and cubic estimations give very similar functional forms, therefore, only the results of the quadratic form were analysed further. The statistical results of the reduced-form model estimation provided by Eviews output are presented in Table 3.

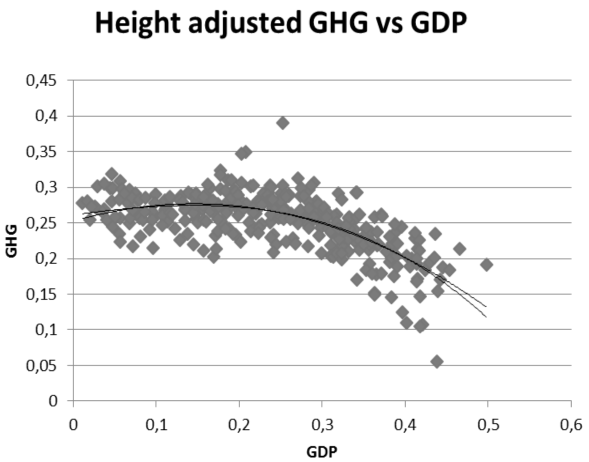

Fig. 1 Comparison of the cubic and quadratic function model estimates (source: made by authors)

Table 3. The results of the reduced model estimation (source: created by authors)

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

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.255256	0.007155	35.67535	0.0000
NNGDP2_?	0.317121	0.055202	5.744778	0.0000
NNGDP2_?^2	–1.134639	0.101911	–11.13366	0.0000
Fixed Effects (Cross)				
LITHUANIA--C	–0.178171			
LATVIA--C	–0.244088			
ESTONIA--C	0.124461			
GREECE--C	0.025695			
SPAIN--C	–0.065334			
ITALY--C	–0.039527			
PORTUGAL--C	–0.130695			
DENMARK--C	0.135919			
BELGIUM--C	0.152293			
FRANCE--C	–0.057982			
GERMANY--C	0.100652			
NETHERLANDS--C	0.153390			
AUSTRIA--C	0.032017			
SWEDEN--C	–0.088904			
UK--C	0.041846			
IRELAND--C	0.289948			
POLAND--C	–0.016136			
SLOVENIA--C	–0.036886			
SLOVAKIA--C	–0.062749			
HUNGARY--C	–0.135747			

Effects Specification

Cross-section fixed (dummy variables)

Weighted Statistics

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

Unweighted Statistics

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

The results of the statistical analysis for the whole period indicate that the model is statistically valid. It can be seen that, in general, the research confirmed the presence of the inverse U-shaped relationship. Emissions can be said to exhibit a meaningful Kuznets relationship with per capita GDP if $\beta_1 > 0$, $\beta_2 < 0$, and if the turning point, -$\beta_1/2\ \beta_2$, is a "reasonably" low number (Selden Song). The analysis of the signs and sizes of coefficients shows that the turning point is around 0.15 normalized GDP/per capita. Hence, it may be considered that, after reaching this point, the trend reverses and a higher level of economic growth results in the environment improvement.

The summarised results of the fixed effect panel model confirm the presence of the inverse U-shaped relationship in the chosen sample, indicating that, at a particular level of GDP and economic growth, the pollution increases, but after reaching some threshold, the trend reverses so that, at a higher development stage, further economic growth leads to the improvement of the environment.

6. Conclusions

The paper considers a common EKC relationship between greenhouse gases and gross domestic product for twenty European countries. The balanced data for the full sample chosen are the panel data of the period from 1995 to 2011. The research confirm the presence of the inverse U-shaped relationship, indicating that, at a particular level of GDP and economic growth, the pollution increases, but after reaching some threshold, the trend reverses so that, at a higher development stage, further economic growth leads to the improvement of the environment.

Further analysis might be extended to include several areas as follows: first area may include a deeper analysis of the influence of the economic shock on the EKC relationship (e. g. the financial crisis in 2008). This analysis may provide more data on the effect of pollution elasticity on economic growth in different countries, given very strong economic growth volatility before and after crisis in some EU countries. Second, additional indicators might be included to clarify the relationship and to determine their impact on the relationship between GHG and GDP. The analysis of this kind might be useful for developing the environmental policy in order to find the best tools for reducing the height of the EKC in the region (e.g. for the Baltic states Lapinskienė *et al.* 2013).

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