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GREENHOUSE GASES EMISSIONS AND ECONOMIC GROWTH – EVIDENCE SUBSTANTIATING THE PRESENCE OF ENVIRONMENTAL KUZNETS CURVE IN THE EU

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Abstract. The paper considers the relationship between greenhouse gas emissions (GHG) as the main variable of climate change and gross domestic product (GDP), using the environmental Kuznets curve (EKC) technique. At early stages of economic growth, EKC indicates the increase of pollution related to the growing use of resources. However, when a certain level of income per capita is reached, the trend reverses and at a higher stage of development, further economic growth leads to improvement of the environment. According to the researchers, this implies that the environmental impact indicator is an inverted U-shaped function of income per capita. In this paper, the cubic equation is used to empirically check the validity of the EKC relationship for European countries. The analysis is based on the survey of EU-27, Norway and Switzerland in the period of 1995–2010. The data is taken from the Eurostat database. To gain some insights into the environmental trends in each country, the article highlights the specific relationship in the country based on the level of its development. The similarities between individual countries are analysed in order to identify their basic common features.

Keywords: greenhouse gases, environmental Kuznets curve, European countries.

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Introduction

Since the 1970s, when the Club of Rome put forth its report Limits to Growth, the environmental quality has been considered as a new prerequisite for economic growth. The world has recognised new challenges and responsibilities for climate change and depleting natural resources (Lee *et al.* 2012; Yazdani-Chamzini *et al.* 2013; Goktan 2014). Environmental economists have been long discussing possible harm of the economic growth on the environment. The discussion focused on the environmental Kuznets curve (EKC), showing the relationship between various indicators of environmental degradation and income per capita expressed by various indicators. Originally, the environmental curve was derived from the Kuznets curve. In 1955, S. Kuznets hypothesized the inverse-U-shaped relationship between income inequality and economic growth. He claimed that at early stages of development, when income per capita is growing, income inequality was supposed to increase; but above the critical income level, the inequality would decline, thereby demonstrating the inverse-U-shaped relationship between the level of income inequality and income growth (Kuznets 1955). This relationship became known as the Kuznets curve. Environmental economists have built on this concept by hypothesizing the same type of relationship between the level of environmental degradation and income growth, in particular, after the appearance of the seminal work by Grossman and Krueger (Grossman, Krueger 1991, 1995). At early stages of economic growth, the degradation and pollution increase; however, beyond a certain level of income per capita, which varies from country to country, the trend reverses so that at high income levels, economic growth leads to environmental improvement. This implies that the environmental impact indicator is the inverted U-shaped function of income per capita (Stern 2004).

In today's world, climate change which is assumed to be caused by human activities (so-called anthropogenic effects) is widely discussed and considered as a major threat to the environment. Over the period of approx. 150 years (starting with the industrial revolution), great amounts of carbon dioxide and other gases causing the so-called greenhouse effect were released into the atmosphere. Based on the assumption that harmful effects produced by human activities cause climate change, researchers are trying to find the methods and ways for interruption of this causal relationship between human activities and climate. The Kyoto Protocol as the main international agreement enforced on 16 February 2005, committed the industrialised countries to stabilisation of GHG emissions. The major feature of the Kyoto Protocol is that it sets targets for 37 industrialised countries and the European Community to reduce greenhouse gas emissions (Kyoto Protocol 1997). Hence, the European Union stated that the prevention of climate change is one of the strategic priorities and encouraged other countries to follow its example. The European Union claimed the reduction of greenhouse gas emissions by at least 20% compared to the levels of 1990 to be one of its strategic priorities (Europe 2020). It also monitored the progress achieved by the EU, its member-states and other EEA member-countries towards their respective targets under the Kyoto Protocol.

The aim of this article is to analyse the relationship between GHG as the main variable of climate change and GDP, using EKC technique, and to empirically check if the statement regarding the EKC relationship between GHG and GDP holds true in European countries.

Specific objectives of this article are as follows:

- to review and assess the available literature on EKC;
- to choose a model and present the EKC for the selected EU countries;
- to group the considered countries based on their EKC patterns.

The analysis was performed in several steps.

Firstly, the sample data was taken to plot the chart of the EKC curve for every country, using the selected model in the period of 1995–2010, and to verify the postulate of the EKC behaviour as the inverted U-shaped relationship between GHG and GDP per capita.

Secondly, the analysis was extended to identify the EKC differences and similarities in various countries, using charts. The countries were differentiated into several groups, and the hypothesis regarding the similarities of EKC at different stages of the country's development was tested.

Thirdly, the results were evaluated for statistical significance and economic logic and the tasks for further research were defined.

The paper has the following structure. Section 1 addresses some important theoretical issues based on considered concepts. Sections 2 and 3 provide a comparative analysis and describe the main findings of the research. The last section summarizes the results, providing the concluding remarks and defining possible areas for further research.

1. Theoretical background

1.1. Original studies

The relationship between economic growth and environmental quality has been widely analysed since 1990s. Many researchers agree that Grossman and Krueger boosted the research in the field. In one of their articles, they used comparable measures of three air pollutants in a cross-section of urban areas located in 42 countries to study the relationship between air quality and economic growth in the context of liberalisation of trade between the United States and Mexico (Grossman, Krueger 1991). This concept was popularised through the World Bank's annual Development Report 1992, using additional environmental indicators and more countries. It was found that the environmental quality monotonically improved (due to reduction of pollutants with the exception of the amount of dissolved oxygen in rivers and CO_2) with the rising level of income (World Bank 1992). Later, Grossman and Krueger (1995) examined the reduced-form relationship between per capita income and various environmental indicators (urban air pollution, the state of the oxygen regime in river basins, faecal contamination of river basins, and contamination of river basins by heavy metals). These works revealed that environmental degradation and income had an inverted U-shaped relationship with pollutants increasing at low levels of income and decreasing with income growing to higher levels; while in most cases the turning point was income per capita amounting to USD 8000 (Grossman, Krueger 1995). Critics thought it was ironic that the above original and highly influential works on EKC were not mentioned (referenced) in the IPAT/Club of Rome debate. Probably, this is not surprising because the EKC concept was originally advanced by trade/development economists in the context of an international trade agreement rather than by environmental/resource economists in the pollution control context (Carson 2010).

Nowadays, the problem of economic growth and environmental quality is also in the focus of many researchers. Esty and Porter used the same relationship of the environment performance with GDP, referring to such indicators as urban SO_2 concentration, urban particulate concentration and energy use. The empirical studies have not revealed an inverted U-shaped environmental Kuznets curve, but a conclusion of the considered research is that better regulation leads to better environmental performance and the strong association between income and environmental performance emphasises the promotion of economic growth as a key mechanism for improvement of environmental results (Esty, Porter 2002). The authors strongly emphasised that current environmental issues were so tangible that they were best addressed with the tools of the strategist, not the philanthropist and have to be widely discussed and evaluated in all areas (Porter *et al*. 2007).

At the political level, new challenges and responsibilities for the changing climate and depleting natural resources are incorporated in sustainable development or green economy concepts, where climate change is highlighted as a priority task. Sustainable development as a pattern of development is analysed by many Lithuanian scientists (Štreimikienė, Barakauskaitė-Jakubauskienė 2012; Lapinskienė 2011; Lapinskienė, Tvaronavičienė 2009; Lapinskienė, Peleckis 2009). The World Economic Forum incorporated the environmental policy and physical environment dimensions into the Sustainable Competitiveness Index (World Economic Forum 2011) to stress the importance of future development. The reduction of greenhouse gas emissions is among the main priorities of the European Union, with the aim of reducing greenhouse gas emissions by at least 20% compared to 1990 levels being one of its strategic priorities (Europe 2020). The need for constant monitoring of the progress achieved by the EU, its member-states and other countries towards their respective targets under the Kyoto Protocol is also emphasised.

1.2. Recent empirical works

It is generally accepted that a number of articles on EKC are based on the works of Grossman and Krueger. Since their issue, a vast amount of articles have been published in such journals as *Ecological Economics, Energy Policy, Energy Economics, Economic Modelling* and many others. The growing deterioration of the environmental quality has sparked efforts for better understanding of environmental degradation reasons and investment in data collection and storage in reliable databases. These studies became possible with the growth of various environment-related databases such as World Bank, OECD, Eurostat and national statistics.

The studies in the considered area can be grouped based on several criteria. Firstly, based on the available statistical data, different environmental quality indicators are selected as independent variables (air pollutants, e.g. CO_2, SO_2, GHG, water indicators, waste and other specific environmental indicators). Secondly, depending on the analysed geographic area, two main data analysis techniques are used: a) time series techniques for a single region or location (Saboori *et al.* 2012; Fosten *et al.* 2012; Esteve, Tamarit 2012; He, Richard 2010; Fodha, Zaghdoud 2010; Akbostanci *et al.* 2009); and b) panel data techniques for the analysis of several regions (Hamit-Haggar 2012; Culas 2012; Akbostanci *et al.* 2009; Huang *et al.* 2008). Other differences can be observed in data sources and used econometric models. Some studies include the additional factors, such as energy price and technological level (Fosten *et al.* 2012), trade openness and population density (Ahmed, Long 2012), political institutions (Cynthia Lin, Liscow 2013).

The analysis of the relationship between GHG (in the early studies carbon dioxide variable) and growth started with the World Bank study. The World Bank analysis of cross-country data from 1980 to 1990 found that the relationship between carbon dioxide and GDP showed increasing trends (World Bank 1992). Cole *et al.* (1997) suggested that meaningful EKCs exist only for local air pollutants while indicators with a more global or indirect impact either increase monotonically with income or else have predicted turning points at high per capita income levels with large standard errors, unless they have been subjected to a multilateral policy initiative. Following this idea, Ansuategi and Marta Escapa (2002) argued that the inverted U-shaped relationship did not hold for GHG and growth and explained that GHG was a special pollutant of global warming phenomena which by itself is of international and intergenerational nature. Galeotti *et al.* (2006) tested various functional forms of carbon dioxide and GDP relationship and found that while there is evidence of an inverted-U pattern for the group of OECD countries, this does not hold true for non-OECD countries as EKC basically increases (slowly concaves). However, some critical researchers believe that EKC framework is by no means the only one that can be used to study the relationship between emissions and other socioeconomic factors. They think that the model is overly simplistic or generally inadequate and the alternative approaches might be much more fruitful (Stern, Ma 2008). In this work, we do not go deeper into this discussion and continue searching for new opportunities in using the EKC model.

Some studies also emphasise the behaviour of EKC in developing countries in order to develop the appropriate environmental policy by using various econometric techniques and highlighting the specific aspects of the curve behaviour. For example, Huang studied 38 industrialised countries in order to test their correspondence to the Kyoto Protocol. The selected sample of these countries was divided into two groups: the economies in transition (e.g. Russia, the Baltic countries, etc.) and the developed countries (e.g. Norway, Austria, etc.). The research revealed that economic development and GHG in economies in transition exhibited a hockey-stick curve trend. The statistical analysis of the developed countries did not provide evidence to support the EKC hypothesis for GHG. The authors emphasised that to achieve the Kyoto Protocol objectives, the parties needed to implement policies, which specifically limit GHG with the aim of retarding the climate change (Huang *et al*. 2008).

Fosten, Morley and Taylor 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 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 relationship 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 mitigation of CO_2 or greenhouse gas emissions and SO_2 emissions will rely more on legislation than 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 (Fosten *et al*. 2012).

Esteve and Tamarit (2012) renewed the research for EKC evidence in Spain, using a linear integrated regression model with multiple structural changes. They emphasised that the turning point in Spain was dated 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 in 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 the 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.

Researchers analysing the EKC relationship between GHG and economic growth highlighted various critical points of this theory, e.g. the econometric consequences of the omitted values, the lack of rigorous statistical testing, the nature of the climate change phenomenon, high sensitivity of the sample of the countries chosen, time period and various economic, demographic and political determinants of pollution. The authors of this article continue the discussion regarding the application of the standard EKC model to the analysis of the relationship between GHG and economic growth, framing this research with the reduced form of EKC.

2. The data and methodology of the analysis

In this analysis, EU-27, Norway and Switzerland were considered to determine the EKC relationship between GHG and GDP. The considered countries are presented in the table below and described using the information regarding the stage of their development. The information on the stage of development of each country is taken from the World Competitiveness Report (2011–2012) and presented in Table 1.

Table 1. Stages of countries' development according to WEF

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

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

The data for the full sample chosen is available in the Eurostat database for the period of 1995–2010. A relatively short period restricted the research to some extent; however, it helped making preliminary conclusions regarding the validity of the EKC hypothesis. Moreover, different development levels of analysed countries helped extending the analysis to include different stages of the country's development; in addition, the hypothesis on the similar pattern of EKC in the countries found at the same development stage was tested.

In this research, greenhouse gases are a dependable variable representing the environmental characteristics. It 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 (Eurostat 2010). The main elements of emitted greenhouse gases were defined in the Kyoto basket protocol as follow: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) (Kyoto protocol 1997). They were aggregated into the variable of greenhouse gas emissions expressed in tonnes as units of CO_2 equivalents.

The independent GDP variable was taken from the Eurostat database (GDP at current prices). According to Eurostat, GDP includes goods and services, which have markets (or could have markets), and products, which are produced by a government and non-profit institutions. GDP per capita is calculated as the ratio of GDP to the average population of a specific year. It is often used as the main indicator of the well-being of a country, since it is a measure of the average income in the considered country. Other potential GDP indicators, such as purchasing-power-parity adjusted GDP and real GDP, are not considered in the article because its objective is to demonstrate the nominal EKC in order to avoid possible distortions of purchasing power-parity recalculation or inflation effect. These expressions of GDP may be used in further research. In general, various GDP expressions are taken by researchers as the main independent variables (Grossman, Krueger 1995; Huang *et al.* 2008).

To test the EKC hypothesis, the econometric model was used to evaluate the relationship between GHG and GDP. Three types of empirical models, including the log-linear, quadratic and cubic forms, are commonly used in the analysis of the EKC hypothesis (Dinda 2004). The authors of this work have chosen the reduced-form cubic equations given below to estimate the relationship between GHG and GDP. The selected model was taken as the most accurate and simple method, which can show the relationships between the considered elements. Other models, such as square and fourth- and fifth-degree models do not demonstrate the reliable relationships between the selected variables. Thus:

$$Y_i = \beta_{0i} + \beta_{1i}X_i + \beta_{2i}X_i^2 + \beta_{3i}X_i^3 + \varepsilon_i,$$

where: Y_i is a dependent variable for country *i*; X_i is an independent variable for country *i*; *i* is the country's number; β is the regression coefficient; ε_i is the estimation error coefficient.

The selected model helped testing several patterns of the environment–economic growth relationship. In the research, the configuration without any additional external variables was adopted and per capita GHG emissions as well as per capita GDP were considered. The model was validated by considering the cubic curve fitting (normal Q–Q plot), the significance of R^2 and *p* values. Since the objective of the work was to compare the EKC patterns for different countries, the reduced form was used to determine the net effect of GDP per capita on GHG. In the framework of the present research, other factors, such as energy prices, the regulation level of particular countries, etc. were not discussed. The estimation and testing of other potential independent factors could be the important issues of further studies.

3. The results obtained in the research

In order to examine the hypothesis, the model was tested using the software R version 2.15.2. The models were calculated based on the data pertaining to every country. The results of the econometric analysis may be discussed from the perspectives of statistical significance of the relationship between per capita GDP and per capita GHG emissions. The cubic curve fitting (normal Q–Q plot), R^2 and p-value are the values, indicating whether the regression fits well. The higher the R^2 value, the better the explanatory power for curve fitting. Specifically, the p-value was used to examine the effect of the independent variable (per capita GDP) on the dependent variable (GHG emissions per capita). 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%. The results of the statistical analysis for the entire period indicate that the model has not yielded any significant results in some cases because the values of R^2 were very small and p-value was bigger than 0.05 (Table 2). To detect the causes of a lower explanatory power, having in mind the financial crisis of 2008, the survey period was shortened to include the years from 1995 to 2008 because, starting from 2008, a substantial GDP fall caused by the crisis could be observed. Further analysis confirmed that this crisis period could distort the causal relationship, particularly, in the most volatile countries (where GDP per capita decreased by 5 or more per cent except for Latvia). The new hypothesis was tested by recalculating the considered model for the reduced period from 1995 to 2008. The performed analysis yielded much better statistical results in most of volatile countries including Estonia, Ireland, Greece, Spain, Italy, Lithuania, Hungary, Slovakia and the UK. The only exception was Latvia with minimal improvement in the statistical significance of the model. The main results of two statistical analyses are presented in Table 2 and explained below. Further research is needed to clarify reasons, for which the causal relationship between GDP and GHG could not be observed during the crisis. Specifically, this research would be important because the preliminary analysis indicated that GHG decreased more than could be explained by observed GDP changes.

Table 2. Regression parameter estimates for the period 1995–2008, and the comparison of R^2 for two considered periods

Country	Period of 1995–2008						Period of 1995–2010	
	β_0	X_1	X_2	X_3	R^2 (1995–2008)	p – value (1995–2008)	R^2 (1995–2010)	p – value (1995–2010)
Belgium	14.05286***	−2.50090***	−0.34832	−0.39385	0.9036	2.161e-05	0.8716	1.2E-05
Bulgaria	8.66214***	−0.01839	1.48714**	−1.23995*	0.6776	0.008055	0.6042	0.00916
Czech Republic	14.2393***	−0.2020	0.1185	−0.8773*	0.3607	0.1967	0.3498	0.1468
Denmark	13.4557***	−4.1335***	0.66338	−0.18161	0.7266	0.003634	0.7571	0.00054
Germany	12.68286***	−2.08932***	0.599599*	−0.04461	0.8994	2.665e-05	0.8735	1.1E-05
Estonia	13.7886***	1.3750	1.9623*	−0.4617	0.5177	0.05455	0.3676	0.1265

Continued Table 2

Country	Period of 1995–2008						Period of 1995–2010	
	β_0	X_1	X_2	X_3	R^2 (1995–2008)	p – value (1995–2008)	R^2 (1995–2010)	p – value (1995–2010)
Ireland	16.9850***	−1.0585*	−2.4598***	0.1698	0.8145	0.0005462	0.3234	0.1815
Greece	11.53786***	1.60057***	−1.08871***	0.14719	0.9329	3.588e-06	0.5965	0.01023
Spain	9.19786***	2.00881***	−2.13435***	−0.22687	0.9128	1.311e-05	0.5329	0.02357
France	9.15071***	−1.32341***	−0.33197*	0.08701	0.9386	2.303e-06	0.8949	3.8E-06
Italy	9.59643***	0.23400*	−0.63480***	−0.66773***	0.9071	1.798e-05	0.3623	0.1323
Cyprus	14.87429***	−0.60406	0.42475	−1.14452*	0.5802	0.02843	0.5039	0.0331
Latvia	4.84000***	0.49507**	0.56850***	−0.60103***	0.832	0.0003359	0.7263	0.00108
Lithuania	6.38929***	1.44048**	0.73665	−0.54504	0.7252	0.003725	0.3994	0.09564
Luxembourg	24.4393***	5.2598**	−1.0954	−5.5623**	0.7934	0.0009262	0.5613	0.01651
Hungary	7.67857***	−0.16015	−0.29391*	−0.33703**	0.6784	0.007962	0.2977	0.2208
Malta	7.09500***	1.20989***	0.08798	−0.22750	0.8283	0.0003741	0.805	0.00015
Netherlands	13.52214***	−2.67869***	0.36204	−0.21308	0.9408	1.918e-06	0.9259	4.7E-07
Austria	10.58429***	0.78321*	−0.85571*	−0.75427*	0.7115	0.004715	0.495	0.03658
Poland	10.47929***	−0.69107	1.46843***	−0.74011*	0.7589	0.001972	0.717	0.00131
Portugal	7.72357***	0.84441**	−1.51433***	−0.28437	0.8498	0.0001932	0.8144	0.00011
Romania	6.9671***	−0.3137	0.5883	−1.0458	0.349	0.2131	0.2469	0.3161
Slovenia	9.88500***	1.28058***	0.08314	−0.02122	0.8387	0.0002746	0.3924	0.1019
Slovakia	9.58714***	−0.69732*	0.06173	−0.03325	0.4902	0.0706	0.695	0.00203
Finland	14.40714***	0.08671	−0.61421	−1.32636	0.2019	0.5008	0.103	0.7159
Sweden	7.87286***	−1.70501	−0.14035	0.06552	0.858	0.0001469	0.6791	0.00273
United Kingdom	11.32357***	−2.18966***	−0.12235	0.32470	0.8656	0.0001118	0.4645	0.05078
Norway	11.84643***	−0.43432*	−0.46870*	0.31135	0.6104	0.01995	0.5722	0.01428
Switzerland	7.25429***	−0.31185**	−0.11374	0.14642	0.5909	0.02515	0.7465	0.00069

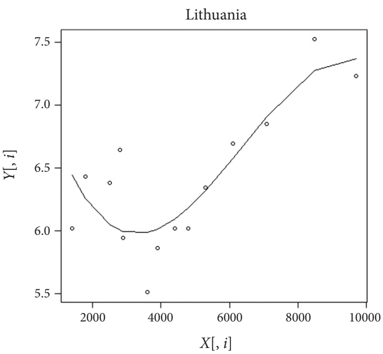
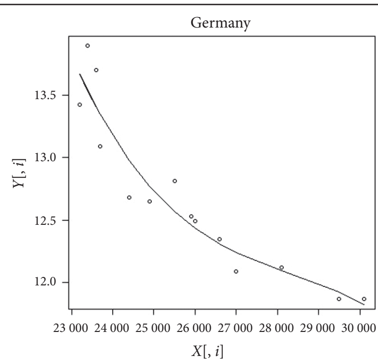
Signif. codes: 0 '***' 0.001 '**' 0.01 '*'

Source: author's calculations.

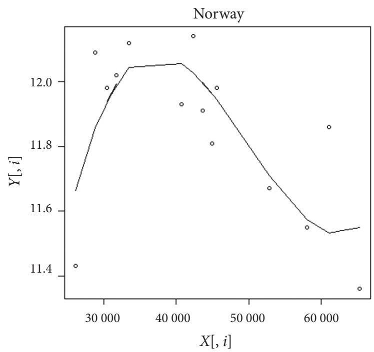
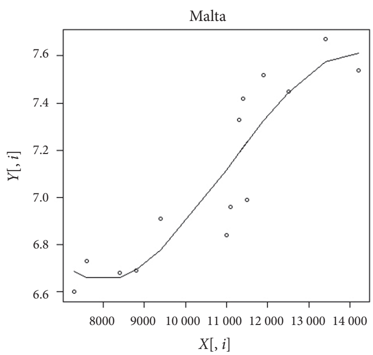
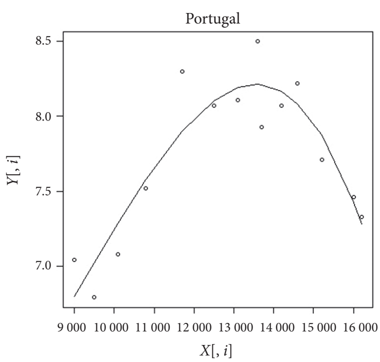
The selected model shows a low explanatory power for four countries (Czech Republic, Romania, Slovakia and Finland) out of 29 states analysed. For the remaining countries, a visual inspection of individual charts and estimated coefficients clearly show different relationship patterns for different states. At the same time, it can be clearly seen that several countries, usually representing similar development levels or geographic areas, have many similarities. The comparison of the relationship patterns is complicated, since the curves have been calculated using different scales because the GDP levels and their observed changes differ among the countries. Therefore, the initial grouping of the countries was made by comparing the estimated regression coefficients and dynamic trends. This is shown in Table 3.

It can be seen that in general, the research confirmed the presence of the inverse U-shaped relationship indicating that at a particular level of GDP and economic growth, the pollution increases; however, once a certain threshold is reached, the trend reverses so that at a higher development stage, further economic growth leads to the improvement of the environment. Still, many questions regarding the turning points remain open because they are different in particular countries. The same applies to tendencies after the country reaches a very high development level, as seen in Norway and Switzerland.

Table 3. Groups of countries based on the EKC pattern

Group	The typical EKC curve	Description
1. Lithuania, Latvia, Estonia, Poland, Bulgaria		The main feature of the EKC pattern of the countries of this group is as follows: at the beginning, it goes downward – the GHG decreases until the turning point is reached and then goes upwards with the GDP growth. It can be noticed that the process of its increasing stops at the top threshold, and then the curve tends to go downwards with the GDP growth. The considered countries have different bottom turning points (Estonia – approximately at 5700 Euro, Latvia – 3900 Euro, Lithuania – 3700 Euro, Poland – 3900 Euro, Bulgaria – 2000 Euro). Although not seen in the results, further economic development of these countries should reach a peak, after which further GDP growth should result in the decrease of GHE. According to WEF, these states are in transition from efficiency-driven to innovation-driven countries. The evaluation of the impact of EU pollution reduction strategies on atmospheric emissions in Lithuania was analysed by Štreimikienė and Bakhyt (2008).
2. Belgium, Denmark, Germany, France, Netherlands, Sweden, UK		This group, including the developed countries, demonstrates positive results and the inverted relationship, when GHG decreases, while GDP per capita increases. This relationship is supported by many economists, proving that, when a certain stage of development is reached, the economic growth leads to better environmental quality (Grossman, Krueger 1995).

Continued Table 3

Group	The typical EKC curve	Description
3. Norway, Ireland, Switzerland		The curve for Norway, Switzerland and Ireland represents the inverted U-shaped relationship, describing the situation, when after the country reaches a certain stage of development, GHG decreases with the increasing GDP per capita. However, later, this positive effect disappears, and the curve becomes almost flat, or starts increasing, which indicates that further economic growth may lead to the increase of GHG.
4. Malta, Slovenia		These countries demonstrate different trends in economic growth, but the patterns of the EKC curves are similar, showing the GHG increase with GDP increase. This may be accounted for some unobserved external factors related to the specific geographic or economic positions of the considered countries.
5. Greece, Spain, Italy, Portugal, Austria, Cyprus, Hungary, Luxembourg		These curves demonstrate the inverted U-shaped relationship, only the top turning points are different (in Greece approximately at 17000 Euro, Spain – 22000 Euro, Italy – 23000 Euro, Portugal – 14000 Euro, Austria – 31000 Euro, Cyprus – 19000 Euro, Hungary – 8500 Euro, Luxemburg – 75000 Euro). However, the peak levels of GHG emissions differ considerably, for example, Luxemburg – 28 t, Hungary – 7,8 t.

Source: author's calculations.

Conclusion

In the performed analysis, twenty-nine European countries were considered to empirically check if the hypothesis regarding the inverted U-shaped EKC relationship between GHG and GDP holds true for European countries in the period of 1995–2010. Standard cubic regression equations were used to estimate the aforementioned relationship. The selected model showed low explanatory power for four countries (Czech Republic, Romania, Slovakia and Finland) out of 29 analysed countries, and these countries were excluded from further analysis. For the remaining countries, the analysis of individual equations and estimated coefficients showed different relationship patterns for different states. At the same time, it can be clearly seen that some countries, representing similar development levels or geographic areas, have some similarities in patterns. The comparison of the relationship patterns is complicated because the GDP levels and the observed changes differ among the countries. Since only a relatively short period was taken for the analysis, not all of the countries demonstrated the accurate inverted U-shaped relationship between GHG and GDP. The countries found to be at a lower development stage (e.g. Lithuania, Latvia, Estonia, Poland and Bulgaria) demonstrate the first part of the inverted U (with GHG and GDP increasing in tandem). The higher developed countries, such as Belgium, Denmark, Germany, France, Netherlands, Sweden and UK, demonstrate the position of the second part with the downwards sloping curve: GHG decreases with increasing GDP per capita. In highly developed countries (e.g. Norway, Ireland and Switzerland), the right side of the curve becomes almost flat or sloping upwards, indicating that further GDP growth can lead to higher GHG emissions.

The findings of the research highlight several areas for further investigation. Firstly, the turning points of EKC in some European countries differ considerably; therefore, the analysis of specific influencing factors may be important for the development and pursuit of the environmental policy. Secondly, the EKC relationship is more stable in the developed countries, while the sharp changes in GDP and other economic factors, observed in more volatile countries during the recent financial and economic crisis, can provide some insight into the factors, having an impact on the shift of the considered EKC.

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