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ECONOMIC DEVELOPMENT AND GREENHOUSE GAS EMISSIONS IN THE EUROPEAN UNION COUNTRIES

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Abstract. The paper analyses the environmental Kuznets curve (EKC) relationship between greenhouse gases and main aspects of economic development based on the panel data of 20 countries of the EU, including the data of three Baltic States, in the period 1995–2011. The fixed effect panel model was used as a framework for the analysis. The commonly used models confirmed the presence of the inverse U-shaped relationship. The novel contribution of this paper is that the factor referring to the global financial crisis was tested in expanded EKC model. Higher energy taxes, primary production of nuclear heat and R&D decrease the level of greenhouse gas emissions (GHG). The size of agriculture, industry and construction, as well as the primary production of solid fuels have a positive sign, which means that a higher value of these indicators is associated with a higher level of GHG. This implies that the analysed set of factors can be applied to adjust the EKC trend in the region and might be useful for the climate change policy adjustment.

Keywords: greenhouse gases, economic development, gross domestic product, environmental Kuznets curve, European Union countries, fixed effect panel model.

JEL Classification: Q56; C33.

Introduction

One of the most relevant environmental problems today is associated with the development of policies, which could help to control climate change. In the strategy "Europe 2020", the target is 20% reduction of greenhouse gas emissions since 1990 till 2020 and the vision of reduction by 80% until 2050. The European Union countries have reduced greenhouse gas emissions (GHG) since 1990, but the target of 20 per cent is yet to be reached.

The problems associated with the harm caused by the economic development (usually, measured by gross domestic product, GDP) to the environment have been discussed by environmental economics. The environmental Kuznets curve appeared to be in the centre of this discussion after the publication of seminal works of Grossman and Krueger

(Grossman, Krueger 1991, 1995). In many cases, it was proposed that this relationship could have the inverted-U form (Holtz-Eakin, Selden 1995; Unruh, Moomaw 1998; Wang *et al.* 2011). In the first stream of EKC studies, reduced EKC models have been estimated without any additional explanatory variables except for GDP proxy variables (Grossman, Krueger 1991, 1995; Shafik, Bandyopadhyay 1992; Holtz-Eakin, Selden 1995). In the later EKC studies, so-called "expanded EKC models" were used, where the relationship between environmental quality indicators and a broader set of economic development variables (GDP, energy consumption, trade openness, urbanization and others) has been investigated (Iwata *et al.* 2011; Baodong, Xiaokun 2011; Esteve, Tamarit 2012; He, Wang 2012; Fujii, Managi 2013; Liao, Cao 2013; Lin, Liscow 2013; Onafowora, Owoye 2014; Yin *et al.* 2015). However, these studies still leave some open questions especially about policy recommendations, which have to be corrected in the course of a country's development. In fact, the effect of the economic growth on the GHG (i.e. the shape of the EKC) is still controversial.

This study provides a new empirical research on the expanded EKC model for twenty European countries in the period 1995–2011. To the best of our knowledge, so far there has been no study that tests the EKC hypothesis for such a sample of countries, specially capturing the three Baltic States. Three variables have been chosen as the classical factors: the scale of economic activity, the share of a particular polluting industry as reflected in the structure of GDP and technological development changes. In addition to this, primary production of solid fuels and nuclear heat and energy taxes were incorporated into one model. The novel contribution of this paper is that the EKC model has been further expanded by specifically testing the impact of the global financial crisis, the aim of inclusion of this specific indicator was to segregate any potential statistical distortion of the impact of the financial crisis of 2008 as it happened in the middle of the analysed time series. In this research, GHG represents a dependable variable of the environmental characteristics. The fixed effect panel model is used for the estimation of the regression; panel unit root tests and panel cointegration tests were carried out to validate the regression characteristics, but due to a comparatively small sample size, some of the statistical characteristics of the model have to be interpreted with care.

The aim of this article is the evaluation of additional factors, which might impact on the relationship between GHG and GDP based on the EKC approach in the chosen sample of EU countries including the Baltic States, in order to track the tendencies of EKC patterns in this region.

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

1. Literature review

The relationship between the economic growth and environmental quality presented by theinverted U has been widely studied since 1990s. Many researchers gave their theoretical explanation why the analysed EKC function might have a particular form. Grossman and Krueger (1995) raised three main hypothetical causes, which impacted on the EKC shape. The scale of economic activity led to the increase of pollution, but altering of the composition of economic activity and the techniques of production changed the path of pollution. The positive effect of composition and techniques might outweigh the negative effect of scale. These three causes can be mentioned as the classical ones. Selden and Song (1994) made the assumption that industrialization and agricultural modernization might lead to increased pollution, while other factors might cause its decrease. Holtz-Eakin and Selden (1995) defined that endogenous variables might be the composition of output, regulations and taxes, patterns of urbanization, etc., and some country-specific factors, including climate, geography, resources, land area, etc., which were mentioned as exogenous variables of emissions. Unruh and Moomaw (1998) suggested that the changes in greenhouse gases emissions trajectories could be based on some shocks or special events in the socio-economic systems. In the latest studies, theoretical causes are defined in groups: equity of income distribution, international trade and pollution heaven, structural change and technological progress, institutional framework and governance and consumer preferences (Kaika, Zervas 2013). All these causes are interrelated, when some particular cases are analysed, it is difficult to identify which one is the main. Following the above logic, researchers used various additional proxy variables to prove empirically their positive or negative impact on the relationship between pollution and GDP. Authors suggested to group the variables into economical, demographic and governance areas (Lamla 2009; Gassebner *et al.* 2011).

The main sources of pollution are associated with the sectors of energy, transport, industry, agriculture and waste disposal, while forestation has a positive effect on the greenhouse gas level. Researchers used various indicators referring to the economic structure: the capital–abundance ratio (K/L) (He, Wang 2012), the percent of the total output of goods and services provided by the industrial sector (Shen 2006; Baodong, Xiaokun 2011), the share of electricity production from coal and oil sources in the total electricity production (Lamla 2009; Wagner 2010; Liao, Cao 2013), the impact of renewable and fossil fuel consumption (Boluk, Mert 2014), energy consumption per capita (Fujii, Managi 2013; Onafowora, Owoye 2014), share of coal consumption in total energy demand to proxy the energy consumption structure (Auffhammer *et al.* 2008; Tiwari *et al.* 2013), electricity produced from the nuclear source as the percentage of the total electricity produced (Iwata *et al.* 2011; Baek 2015).

Furthermore, the role of technological progress in CO_2 emissions should not be neglected. Auffhammer *et al.* (2008) used both energy intensity and time trend to proxy technology progress in the study. Energy intensity is used to capture the heterogeneity and variation in technology progress across provinces, while time trend is employed to control for exogenous technology shocks common to all of the provinces. Neumayer

(2002) include a linear technology variable (approximated by a time trend) in their EKC analysis and find a monotonic relationship with this variable and various measures of environmental degradation. The technological variable used in the study performed by Lantz and Feng (2006) analysis is a simple quadratic time trend. This specification will capture the aggregate impact of technological advances and production structure changes in the economy.

The next strand in investigating the emission dynamics is to test the relationship between the dynamics of political–governance factors. Researchers used such variables as a composite index measuring the quality of political rights and civil liberties (Lin, Liscow 2013), other variables measuring whether or not the party of the chief executive has a left-wing orientation as well as the form of government – dictatorship or democracy; as well as democracy index (Mills, Waite 2009; Gassebner *et al.* 2011; Wong, Lewis 2013), and the level of corruption (Cole 2007).

Based on theoretical studies, economic logic and available statistical variables for the chosen sample of EU countries, several factors were chosen for the estimation of the expanded EKC model which is presented in the following sections.

2. Modelling framework

In this research, GHG represents a dependable variable of the environmental characteristics. In the EKC models, the GDP per capita has been taken as the variable capturing the activities and welfare of the particular state's citizens, which is assumed to impact on the form of the EKC. GDP expressed in purchasing power parity is specifically used in this research for minimizing the potential differences in prices between the countries, which may arise at different stages of development. In general, industry tends to be more pollution intensive than the service sector. In this article, a proxy variable representing the share of polluting industry in the country is the share of value added in agriculture, industry and construction sectors. Primary production of solid fuels and nuclear heat are two variables referring to the country-specific factors. The classical solution to maintain growth and decrease pollution is to develop new technologies, especially those that bring positive economic productivity effects and are environmentally friendly. In this research, several variables were tested as potential factors representing R&D level and trends in the economy, including direct R&D expenditures. Due to different starting points and trends of R&D changes in countries analysed and limited time horizon such variables have not produced econometrically valid results. Hence, a dummy variable showing a constant growth trend (TIME) is used as a proxy variable (Neumayer 2002; Lantz, Feng 2006; Auffhammer *et al.* 2008). In this analysis, a tax variable was chosen to estimate a statistical impact of the potential policy options for negative externalities. Energy taxes is one of the factors affecting the market mechanism forces playing out in EKC analysis and which can be actively managed by policy makers. The model was further expanded by a proxy of the timing of 2008 financial crisis, in order to segregate any potential statistical distortion of the impact of the crisis on the analysed relationship. In this research "Cris08" consists of dummy variables, which is equal to 1 for the year 2008 and are equal to zero for the remaining period and "Cris" consist of dummy variables equal to 1 for the years 2009–2011 and 0 for the remaining years. In 2007, the crisis, which initially affected the financial system of the United States, shortly spread all over the world and stimulated the economic recession, with both business and ordinary citizens suffering from its consequences.

Following the analysed literature and the modelling framework, the hypothesis was raised that all the selected variables have a statistically significant impact and economically expected relationship to GHG as presented in Table 1.

Table 1. Chosen proxy variables affecting EKC

Proxy variables	Description of a proxy variable	Eviews code (Annex 1)	Expected sign
GDP per capita	GDP in PPS (Euro per capita)	GDP	Positive
The share of a particular polluting industry	Agriculture + Industry + Construction value added as a percentage of the total GDP	SECT	Positive
Time (R&D)	Time – a dummy variable showing a constant grow trend is used as a proxy variable instead of the original R&D variable	Time	Negative
Energy taxes	Ratio of energy tax revenues to the final energy consumption (Euro per tonne)	ENERGTAX	Negative
Solid fuels (primary production)	Supply, transformation, consumption of solid fuels – annual data (Tonnes of oil equivalent (TOE)/per inhab)	SOLID	Positive
Nuclear heat, (primary production)	Supply, transformation of nuclear energy - annual data (UNIT – Tonnes of oil equivalent (TOE)/per inhab)	NUCLEAR	Negative
Crises	The dummy variables to estimate the potential impact for the years of the crisis.	CRIS, CRIS08	Positive or negative

Source: created by authors.

In order to test the statistical significance of these variables and to prove the hypothesis raised, the expanded quadratic EKC equation was used for the estimation. The selected model for this step of the research is given below:

$$\begin{aligned} GHG_{it} &= \alpha + \mu_i + \beta_1 GDP_{it} + \beta_2 GDP_{it}^{\;2} + \beta_3 SECT_{it} + \beta_4 TIME_i + \beta_5 ENEGTAX_{it} + \\ &\beta_6 SOLID_{it} + \beta_7 NUCLEAR_{it} + \beta_8 CRIS08_{it} + \beta_9 CRIS_{it} + \varepsilon_{it}, \end{aligned} \tag{1}$$

where GHG_{it} is a dependent variable for the country i in the time t; GDP_{it}, $SECT_{it}$, $TIME_t$, $ENERTAX_{it}$, $SOLID_{it}$, $NUCLEAR_{it}$, $CRIS08_t$, $CRIS_t$ are the independent variables for the country i in the time t; β denotes the regression coefficients; μ_i is the cross–section specific effect; ε it is an error term.

The study employs the equation form used by Holtz-Eakin and Selden (1995), Wang *et al.* (2011), He and Wang (2012), Fujii and Managi (2013), and Boluk and Mert (2014). The study follows the panel data analysis performed by Marrero (2010), Boluk and Mert (2014), and Lopez-Menendez *et al.* (2014).

3. Empirical analysis

3.1. Sample and data

In this analysis, twenty European states (Annex 1) were considered to determine the expanded EKC model relationship between GHG and GDP. In this study, Bulgaria, Romania and Croatia were not included, as these countries joined the European Union only recently (2007 and 2013); therefore, these countries had a short period for the implementation of the European Union policies. Luxemburg, Cyprus and Malta were not analysed either because their population is less than 1 million, which may distort calculations of per capita terms. Finland and the Czech Republic were excluded after calculating separate multiple regressions for the remaining 22 European countries because the models of these two countries did not show the statistical significance (Lapinskienė *et al.* 2013, 2014).

The empirical study is based on the panel data; therefore, the econometric fixed effect panel data model is used for testing the hypothesis. In order to have the comparable data, the data sets for the analysis are chosen from Eurostat. 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 in quadratic model estimation, the data for GHG and GDP were normalised to vary between 0 and 1, where the smallest value of the whole EU sample is equal to 0, and the largest value is equal to 1. At the same time, this facilitates the comparison of the results, as for example 0.5 equals to the average EU level.

3.2. Panel unit root tests

For the panel model estimation, the Eviews software was used. The testing procedure consists of panel unit root tests, panel cointegration tests and the estimation of the multiple regression model coefficients following other researchers (Wang *et al.* 2011; Pedroni 2004). The panel unit root and cointegration tests used in the paper are generally used for panels involving a smaller cross-section than a timespan. However, the size of a timespan is smaller than that of a cross-section in the panel used in this article. Consequently, the results obtained from our empirical study should be interpreted with this limitation in mind.

In panel data analysis, the panel unit root test must be taken first in order to identify the stationary properties of the relevant variables. In this study, we choose Standard Eviews-produced panel unit root tests, namely, Levin–Lin–Chu test, Im–Pesaran–Shin test and Maddala–Wu test by Lean and Smyth (2010) and Wang (2011), to enhance the robustness of the results.

Table 2 shows the results of the panel unit root tests for each variable (except for dummy variables). It can be seen that the variables NNGGE, NNGDP2, NNGDP2^2 and SECT in level form are statistically insignificant and, therefore, non-stationary. The level of ENERGTAX is statistically significant under all panel unit root tests produced. However, after first-order differencing, it is found that all the variables become stationary. Therefore, we may conclude that each variable is integrated of order one, i.e. I(1).

Table 2. Pool unit root tests: summary

Variable	Levin, Lin & Chu		Im, Pesaran and Shin W-stat		ADF – Fisher Chi-square		PP – Fisher Chi-square	
	Level	First diff.	Level	First diff.	Level	First diff.	Level	First diff.
NNGGE	3.10018 (0.9990)	0.08089 (0.5322)	3.54282 (0.9998)	–4.43301 (0.0000)	25.7804 (0.9602)	87.3971 (0.0000)	25.6556 (0.9618)	215.462 (0.0000)
NNGDP2	–1.15269 (0.1245)	–8.15661 (0.0000)	3.51816 (0.9998)	–5.40102 (0.0000)	14.4888 (0.9999)	102.701 (0.0000)	58.1066 (0.0320)	136.405 (0.0000)
NNGDP2^2	–1.15269 (0.1245)	–9.48257 (0.0000)	3.51816 (0.9998)	–6.61337 (0.0000)	14.4888 (0.9999)	121.199 (0.0000)	21.5976 (0.9923)	158.595 (0.0000)
ENERGTAX_?	158.595 (0.0000)	–4.01469 (0.0000)	–2.54070 (0.0055)	–5.32789 (0.0000)	64.5619 (0.0082)	102.135 (0.0000)	93.2248 (0.0000)	216.731 (0.0000)
SECT_?	–2.13132 (0.0165)	–7.84358 (0.0000)	0.51631 (0.6972)	–6.26949 (0.0000)	34.6520 (0.7093)	110.755 (0.0000)	49.2431 (0.1500)	191.790 (0.0000)

3.3. Panel cointegration tests

In order to ascertain that the regression of the model is not spurious, the results of panel cointegration tests need to be checked. Several cointegration tests suggested by Pedroni (1999) and Kao (1999) were employed, bearing in mind that sample size is small, and the number of cross sections is comparatively high. The results of tests are provided in Table 3. The first tests by Kao indicate that the full model is panel cointegrated with 1% significance level. On the other hand, only t-statistics tests of Pedroni (Panel PP-Statistic, Panel ADF-Statistic and Group PP-Statistic and Group ADF-statistics) reject the null of no cointegration with more than 1% significance level. It should be noted that these are the most powerful, given our sample size, according to Pedroni's (2004), for the small panel data set with the number of cross section units being about 20 and the number of time units being about 30, the empirical powers of panel and group t-statistics are roughly twice as large as the other test statistics. Considering the facts that the rho-statistics has lower power, at the same time bearing in mind small data set, it may be reasonable to accept the existence of cointegration relationship.

3.4. Empirical results

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: R^2 and *Adjusted* R^2; P-values of Fisher and Student tests and residuals. 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%.

Table 3. Cointegration Test output

Pedroni Residual Cointegration Test		
Alternative hypothesis:	common AR coefs. (within-dimension)	
	t-Statistic	Prob.
Panel v-Statistic	–2.377357	0.9913
Panel rho-Statistic	1.520727	0.9358
Panel PP-Statistic	–9.145355	0.0000
Panel ADF-Statistic	–8.205970	0.0000
Alternative hypothesis: individual AR coefs. (between-dimension)		
	t-Statistic	Prob.
Group rho-Statistic	3.168898	0.9992
Group PP-Statistic	–9.510796	0.0000
Group ADF-Statistic	–7.792694	0.0000
Kao Residual Cointegration Test		
	t-Statistic	Prob.
ADF	–2.745064	0.0030

Full results of model estimation output are provided in Annex 1. The model was validated by the characteristics of the fitted model. R^2 is 0.982, and Adjusted R^2 is 0.981. R^2 is very high due to its estimation specific for pooled data series. The P-value of Student's test provided in the column 'Prob' was used to determine the statistical significance of the estimated coefficients of the proxy variables. F–statistics of the final extended quadratic model is 478.5672 and probability of F–statistics being zero is non–existent. In this case, Durbin–Watson stat is 0.893048, indicating a substantial serial correlation of the residuals.

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

The expanded model has nine indicators, which can decrease the reliability of the model. Despite this, the parameters of the model are in agreement with the theoretical econometric methodology and economic logic. Summing up the results of the estimation, several conclusions could be made. First, based on mathematical logic, the expanded model may not show the existence of the EKC form because additional variables change the form of a function. However, the signs of the coefficients by $GDP > 0$ and $GDP^2 < 0$ indicate that it could be a form of the inverted U. Second, the existence of differences between the pollution levels, i.e. the height of EKC, not captured by the factors analysed, in different countries in the model is demonstrated by the differences between a country's intercepts (see data in Annex 1). Third, the factors influencing the analysed relationship may be subdivided into several groups reflecting structural characteristics and technological progress, as well as policy options. Structural characteristics comprise

Table 4. Comparison of expected and obtained coefficient signs

Proxy variables	Eviews code	Estimation coefficient (significance level)	Signs of coefficients	
			Expected sign	Final results
GDP per capita	GDP GDP^2	1.081286 (0.000) –1.425350 (0.000)	Positive Negative	Positive Negative
The share of a particular polluting industry	SECT	0.003950 (0.000)	Positive	Positive
Time (R&D)	TIME	–0.005286 (0.000)	Negative	Negative
Energy taxes	ENERGTAX	–0.000455 (0.000)	Negative	Negative
Solid fuels (primary production)	SOLID	0.015518 (0.000)	Positive	Positive
Nuclear heat (primary production)	NUCLEAR	–0.023622 (0.0015)	Negative	Negative
Crises	CRIS, CRIS08	–0.008704 (0.0001) –0.015817 (0.0006)	Positive or negative	Negative

such factors as the sectorial structure, primary production of solid fuels and nuclear energy and the global financial crises as an external event. Technological progress and production structure changes in the economy embodied the level of R&D. Taxes variable was chosen as a potential policy option for negative externalities.

In general, it can be seen in Table 4 that the considered indicators produce a statistically significant effect. The regression coefficients referring to GDP, the share of a particular polluting industry and primary production of solid fuels have a positive sign, while time (R&D), energy tax, the dummy variables of crises and primary production of nuclear heat have a negative sign.

The existence of differences between pollution levels in different countries not explained by the analysed variables is demonstrated by the remaining differences between a country's intercepts (i.e. the height of EKC). The higher is the intercept of a country, the higher is the unadjusted GHG level. As a general case, countries having a higher development level tend to have a higher EKC (Denmark, Ireland), while less developed countries have a lower EKC (Latvia, Lithuania). The applied EKC estimation method allows evaluating the specific effect of a variable not only on the form but also on the height of EKC (having other effects fixed).

It was expected to get a positive sign of the economic structure, and it had been obtained. Optimisation of the structure of the three industries needed a long development process. Appropriate reduction in the proportion of highly-polluting sectors and the development of the service sector, high-tech sector and other tertiary industries may reduce the pollution emission. This conclusion is in line with the conclusions of Shen (2006), Baodong and Xiaokun (2011), He and Wang (2012).

The quantity of primary production of coal and lignite directly affects the level of GHG, and it is an easy way to explain. The results are in line with those achieved by other researchers (Lamla 2009; Iwata *et al.* 2011; Boluk, Mert 2014). The increase of nuclear heat (primary production) reduces the level of GHG, and the conclusion is in line with the conclusions of Iwata *et al.* (2011). It is important to note that, although nuclear power plays an important role in reducing CO_2 emissions as found empirically, the management of nuclear power plants always involves some risks, besides, they are highly dependent on wide cross-country variations in social, economic and political factors.

The regression coefficients next to variables referring to the global financial crisis have a negative sign, which means that during these crises, short-term changes in economic relationships decreased the GHG level even more than indicated by the slowing economic growth. It leads to a conclusion that the level of GHG could be impacted by unexpected shocks.

The traditional EKC theory pointed out that the technological effect is one of the factors, which drive the declining part of EKC throughout the entire period of economic development. "Time", used as an alternative proxy in this work, produces statistically significant results and reduces the level of GHG. There is still a wide gap within the EU countries and unknown lag of the R&D impact as indicated by statistical difficulties of direct inclusion of the variable of R&D expenses into the model. It takes some time from the R&D input to transfer it into technical improvements and eventually to promote social technical progress. Many researchers highlighted potential problems related to the correct estimation of R&D proxy due to differences in specific countries and an unknown time lag of the R&D impact; nevertheless, the same direction was proved by Auffhammer *et al.* (2008), Neumayer (2002), Yin *et al.* (2015). If policy-makers paid more attention to the distribution of the R&D investment and specific goals, the time lag might be shortened and should have a positive influence on reducing the GHG emissions. Strengthened environmental regulation, while focusing on the improvement of the technical level, increasing the R&D effort and the introduction of advanced environmental technologies, should be among the aims of the climate change policy.

The effective measure used in the environmental policy is associated with the energy taxes. The results obtained show that their growth helps to reduce the level of GHG and is in line with Brannlund *et al.* (2014). As useful welfare policies, environmental regulations can control pollution overall and thus produce similar joint action on controlling the GHG emissions, but it may generate environmental inequities.

Also, it should be noted that other development policy and structure variables, which are not included in this study, might also have affected the pollution income trajectory in the EU during the period of 1995–2011. It is practically impossible to include all of the important structural and policy variables in one model.

Conclusions

The estimation of the effects produced on GHG by the economic growth and related various external factors can be viewed as a tool supporting a country's strategic decision. In this paper, the expanded EKC model estimating the relationship between GHG and GDP and some additional factors (e.g. the share of a particular polluting industry, time (R&D), primary production of solid fuels and nuclear heat, energy taxes as well as the dummy variables representing crises) for the twenty EU countries (including three Baltic States) is tested empirically. The analysis of the expanded model, covering the relevant factors, allows assessing the impact of economic variables on GHG emissions, in order to manage the harmful effect of the economic growth on the environment. In order to test the effects of different factors in the European Union countries, the estimation was made by the fixed effect panel model, the econometric techniques such as panel unit root tests, panel cointegration, as well as estimation of regression characteristics were adopted. In general, the research confirmed the presence of the inverse U-shaped relationship. Hence, countries having a higher development level tend to be on the higher phase of EKC (Denmark, Ireland), while countries which are less developed are on the lower phase EKC (Latvia, Lithuania). The empirical expanded EKC model estimation suggests that the analysed factors are relevant for the management of climate change as they demonstrate a statistically significant effect on the dynamics of GHG. The size of agriculture, industry and construction negatively affects the level of GHG. The variable of the primary production of solid fuels has a positive sign. The regression coefficients next to primary production of nuclear energy have a negative sign. The regression coefficients next to energy taxes have a negative sign as expected. The R&D proxy has a negative sign, which means that a higher value of these indicators is associated with a lower level of GHG.

Unlike previous studies of EKC, this paper tested the period including the financial crisis years. The initial analysis confirmed that the international financial crisis (that started at the end of 2008) had an impact on the results of the analysis, particularly, in the countries where the economic growth rate was most volatile.

The obtained model coefficient estimates could be directly used as a basis to estimate various scenarios, in order to see the potential future path of the GHG development for a country or region. The obtained results show that the future path of EKC could depend on the development level of a specific country. In countries that achieved a higher development level and reached the EKC turning point, the GDP increase would positively impact on the level of GHG. In the Baltic States and Central and Eastern European countries, which have not yet reached the EKC turning point, some additional environmental measures (including changes in the structure of the economy, energy taxes and others) might be used as instruments in the climate change policy adjustment. The further analysis might be extended into some other areas. Using the proposed technique, other environmental variables could be tested. Another direction of studies may be related to the deeper analysis of the economic shocks with respect to the EKC relationship.

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ANNEX 1

Dependent variable: NNGGE_?
Method: Pooled EGLS (Cross-section weights)
Date: 12/30/14 Time: 13:56
Sample: 1995–2011
Included observations: 17
Cross-sections included: 20
Total pool (balanced) observations: 340
Linear estimation after one-step weighting matrix
White cross-section standard errors & covariance (no d.f. correction)

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.081154	0.028635	2.834088	0.0049
GDP_?	1.081286	0.082786	13.06119	0.0000
GDP_?^2	–1.425350	0.078041	–18.26409	0.0000
TIME	–0.005286	0.000789	–6.697535	0.0000
ENERGTAX_?	–0.000455	7.12E-05	–6.395090	0.0000
SECT_?	0.003950	0.000696	5.673999	0.0000
SOLID_?	0.015518	0.001644	9.438513	0.0000
NUCLEAR_?	–0.023622	0.007376	–3.202557	0.0015
CRIS08	–0.008704	0.002246	–3.876067	0.0001
CRIS	–0.015817	0.004536	–3.486820	0.0006
Fixed Effects (Cross)				
LITHUANIA--C	–0.102042			
LATVIA--C	–0.153767			
ESTONIA--C	0.006132			
GREECE--C	–0.010645			
SPAIN--C	–0.067597			
ITALY--C	–0.012457			
PORTUGAL--C	–0.076073			
DENMARK--C	0.163406			
BELGIUM--C	0.135257			
FRANCE--C	–0.002172			
GERMANY--C	0.053200			
NETHERLANDS--C	0.122761			
AUSTRIA--C	–0.027249			

Variable	Coefficient	Std. error	t-statistic	Prob.
SWEDEN--C	–0.060337			
UK--C	0.069612			
IRELAND--C	0.185393			
POLAND--C	–0.027935			
SLOVENIA--C	–0.047069			
SLOVAKIA--C	–0.046549			
HUNGARY--C	–0.101868			
Effects specification				
Cross-section fixed (dummy variables)				
Weighted statistics				
R-squared	0.982162	Mean dependent var.		0.331367
Adjusted R-squared	0.980556	S.D. dependent var.		0.206067
S.E. of regression	0.020332	Sum squared resid.		0.128566
F-statistic	611.5747	Durbin-Watson stat.		0.893048
Prob(F-statistic)	0.000000			
Unweighted statistics				
R-squared	0.972661	Mean dependent var.		0.251643
Sum squared resid.	0.133756	Durbin-Watson stat.		0.759273

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