Ekonomia. Rynek, gospodarka, społeczeństwo
44(2016), s. 31−50
DOI: 10.17451/eko/44/2016/144
ISSN 0137-3056
www.ekonomia.wne.uw.edu.pl

Decomposition of carbon dioxide and sulphur oxides emissions intensity change in the European Union*

Mariya Hnatyshyn**

Abstract

The paper tests the environmental Kuznets curve hypothesis, pollution havens hypothesis and evaluates primary energy consumption impacts on emissions. Changes in emissions of examined pollutants in the European Union are in line with the environmental Kuznets curve hypothesis. The turning point is the highest for CO_2 and four times lower for SO_x. These results indicate that as the economy grows the demand for a clean local environment grows first, and is followed by the demand for clean global environment. More intense external trade reduces CO_2 and SO_x emissions, which provides evidence for the pollution havens hypothesis. Primary energy consumption in the EU has a statistically significant positive effect on examined emissions. Europe's energy sector (and Polish in particular) is very dependent on fossil fuels. Despite the existing problems, the EU can serve as an example of sustainable development for less developed countries.

Keywords: economic development, the European Union, environmental Kuznets curve, pollution havens hypothesis, primary energy consumption.
JEL Codes: O10; O13; F18; Q25; Q40
DOI: 10.17451/eko/44/2016/144

* The article is written on the basis of the research conducted within the framework of the Lane Kirkland Scholarship Programme (Polish-American Freedom Foundation).
** Ivan Franko National University of Lviv, Faculty of Economics, Analytical Economy and International Economics Department; e-mail: hnatyshyn.maria@gmail.com.

1. Introduction

The modern world is characterized by a high level of globalization, large scale of global economy and high anthropogenic pressures on the environment. Human economic activity embraces the whole planet. There is hardly any ecosystem left unaffected by human activity. The capabilities of natural environment to resist anthropogenic pressure set limits for economic development in the traditional sense of the term. Over the last 30 years a number of empirical works studying the impact of economic growth on different indicators of environmental quality have emerged. A number of theories and hypotheses have been formed to explain the problem, introducing environmental concerns into traditional economics. Among the many hypotheses, explaining the impact of economic growth on the natural environment, the Environmental Kuznets Curve hypothesis (EKC) is the most popular one. According to this hypothesis there is a relationship between economic growth and the state of the natural environment in the shape of an inverted "U" curve. When an economy grows at the low level of income, pollution initially grows because of increased production generated pollution. At a higher level of income further economic growth causes pollution to decline. Most likely it is due to priorities shift to environmental quality protection.

An empirical analysis of the EKC for the European Union is one of the main purposes of this work. We also look for the evidence for the pollution havens hypothesis and evaluate the influence of energy consumption on emissions. According to the pollution havens hypothesis polluting industries tend to migrate to less developed countries because of lax environmental regulations.

The paper contains an econometric study of the effects of economic growth, of the intensity of external trade, and of the primary energy consumption on emissions in 28 EU countries. The main objective of this study is to answer the questions: Does the EKC work for the EU and at what level of income do the emissions start to decrease? How does the impact of economic growth on emissions differ depending on the type of pollution? Does the intensification of external trade cause the emissions to decrease? Does the increase in energy consumption cause the emissions to increase?

The structure of the paper is as follows. The first chapter presents an analysis of theoretical, analytical and empirical works exploring the EKC. The next chapters contain an econometric study of the EKC hypothesis for the EU, including a description of data, a model and results of the model estimation. In those chapters the impact of GDP growth, of external trade intensity and of primary energy consumption on emissions is investigated. In the last chapter, the results are discussed, and conclusions are made concerning the impact of economic development on the natural environment.

2. Previous studies

The first study identifying the existence of the EKC was conducted by Grossman and Krueger (1993). It was an attempt to assess the overall impact of economic growth on the environment (caused by the adoption of North American Free Trade Agreement). The results of that research revealed that along with the increase in real income the air quality at first deteriorates, but begins to improve after reaching a per capita income of 5,000 USD per year.

Later on, many studies on the existence of the EKC emerged. They were conducted regarding various types of pollution, different regions and different time periods. The literature review shows that scientists have identified relationships in the form of inverted U, in the form of U, in the form of N, as well as constantly growing or declining linear relationships depending on the types of pollution, countries and other specifications.

A good comprehensive analysis of the EKC studies was conducted by Stern (2004). According to Stern (2004), the earliest attempts to estimate the EKC were in the form of a simple square function of income level. But he points out a problem with that. Economic activity inevitably involves the use of resources and by the laws of thermodynamics the use of resources inevitably involves the production of waste. Regression that allows pollution levels to become zero or negative is in most cases inappropriate except for deforestation, which can be substituted by afforestation. This restriction is imposed by the logarithmic dependent variable. Some researchers, including Grossman and Krueger, also used cubic EKC and detected an N-shaped EKC. Stern (2004) suggests that it might just be a polynomial approximation to a logarithmic curve. So far, the standard way to determine the existence of the EKC is by estimating the square function of logarithmic variable of income, which we use in the model in chapter 3.

Besides Stern (2004), many other scientists analyze and systemize already conducted studies of the EKC: Dasgupta *et al.* (2002); Dinda (2004); Alstine and Neumayer (2010); Olivier *et al.* (2014) and others. So far there is no need to provide yet another overview of the EKC studies. That is why we pay attention to only some of the numerous empirical studies which, in our opinion, are most related to the problem of the present study.

The first empirical study on CO_2 emissions is the work by Shafic and Bondyopadhyay (1992) which was conducted for the World Bank. Scientists used ten indicators of environmental quality as dependent variables and estimated a panel regression using data from 149 countries for the years 1960−1990. According to their results, income has a significant impact on all indicators of environmental quality. The most common environmental indicators initially worsen with an increase in income, but then they tend to improve as countries become richer. The emissions of carbon dioxide were found to be the exception. They increase monotonically with increasing income (Kaika and Zervas 2011).

Bouvier (2004) finds in his work the evidence on the EKC. He attempts to separate the economies of scale and then assesses the effects of variables related to structural and technology effects. The types of contaminants studied in this work are: carbon monoxide, carbon dioxide, sulfur dioxide, and volatile organic compounds. According to the model assessment, ordinary coefficient and square coefficient of the income trend indicate a relationship in the form of an inverted U. However, the turning point occurs at around 17,400 USD (in 1987 international USD). Bouvier (2004) believes that with the turning point occurring at such a high level of income, it is not worth hoping for the reduction of carbon dioxide emissions worldwide in the near future.

Cole (2004) examines the extent to which the inverted U relationship between income growth and pollution levels can be explained by foreign trade and relocation of "dirty" industries from developed regions to developing countries (pollution haven hypothesis). The most pollution-intensive sectors ISIC 34-37 and the cleanest ISIC sectors 32, 38 and 39 are considered in the paper. Cole (2004) estimates the equation for OECD countries. He takes into account not only income per capita but also the share of manufacturing in GDP, the share of "dirty" exports to countries outside the OECD in general exports, the share of "dirty" imports from non-OECD countries in general imports and intensity of foreign trade.

The results of a EKC analysis in this case are as follows: for each kind of pollution (CO_2, NO_x, SO_2, CO and VOC SPM) there is a robust, statistically significant relationship with per capita income. For most pollutants Cole obtained an EKC relationship. The share of pollution intensive imports and exports between OECD and non-OECD countries at least partly explains emissions and indicators of environmental quality. The pollution haven effect is not characteristic for all pollutants. Even if this effect is found, the estimated elasticity for the independent variable of the share of "dirty" trade is generally smaller than for income, trade openness and the share of manufacturing. Emissions of air pollutants according to Cole (2004) are particularly inversely related with the share of the "dirty" imports from developing countries. Moreover, the turning point occurs at a higher level of revenue compared with a model where the effects of imports have been omitted. This suggests that such effects are captured by the impact of income if they are not controlled for separately. Cole notes that the share of manufacturing in GDP has generally a statistically significant positive relationship with pollution. So reducing the share of industry in GDP has proven to decrease emissions in the OECD countries. When he controls for structural changes, income and possible pollution havens effects, trade openness still shows statistically significant negative relationship with pollution (Cole 2004).

Farhani and Ben Rejeb (2012) conducted a study of causal links between economic growth (GDP), energy consumption and CO_2 emissions for 15 MENA countries. They did not test the EKC, but they considered the impact of energy consumption on emissions. That is why the study is of interest to us. The empirical results show that in the short term, energy consumption has an impact on CO_2 emissions and economic growth. The increase in energy consumption can lead to the growth of income and CO_2 emissions. Energy efficiency policy might not interfere with economic growth and income growth. Based on the results of their work Farhani and Ben Rejeb (2012) propose the following recommendations: when energy consumption causes economic growth, this suggests that the benefits of energy use are higher than the external costs of energy consumption. Conversely, if the increase in the rate of economic growth increases the energy consumption, the externalities of energy use will set back economic growth. In this situation the environmental policy is necessary.

Apart from studies on EKC for country groups, there have been numerous studies conducted for separate countries. Omay (2013) examines the impact of economic growth on CO_2 emissions in Turkey. The results show, that the relationship between CO_2 emissions and economic growth is formed in the shape of letter N, so the results do not confirm the hypothesis of EKC in its traditional form.

Shahbaz, Lean and Shahbaz Shabbir (2010) studied emissions in Pakistan. Their work is of a particular interest to us, as it examines the relationship between CO_2 emissions, energy consumption, economic growth and trade openness. The research of Shahbaz, Lean and Shahbaz Shabbir (2010) is not a panel research, and they do not take other types of pollution into account, but nevertheless the results of the study are interesting. According to the research, the EKC hypothesis holds true for Pakistan. Moreover, they found an unilateral causal effect of income on CO_2 emissions. Energy consumption increases CO_2 emissions, both in the short and in the long run. Trade openness reduces CO_2 emissions in the long run, while in the short run the reduction of emissions is irrelevant.

Having so many predecessors in the area of EKC studies it is a highly responsible task to conduct another one. That is why it is important to take into account recommendations given by Alstine and Neumayer (2010) when analyzing the results of empirical studies of that kind. First of all, for some kinds of pollution there can be no turning point. Most often no turning point is found for CO_2, direct material flows and biodiversity loss. Secondly, the econometric results are based on historical and current data and that is why the results are not deterministic for the future. So prognoses are not highly reliable. Thirdly, even if there is a turning point, there is a possibility of another one. Fourthly, there is often a need to use country-specific fixed and year-specific time effects. Country-specific fixed effects are needed when GDP per capita or other explanatory variables are correlated with country-specific time-invariant factors e.g. geographical factors or institutional quality. This aspect is relevant to our research. Time-specific effects are needed when there have been some global changes influencing the state of the environment in all countries e.g. due to global advances in technology. Fifthly, when country-specific fixed effects are used the results are dependent on those effects specific for the sample of countries. So far, it is impossible to make any predictions for out-of-sample countries based on the estimation results. Sixthly, if environmental indicator and GDP per capita are both trending over time, regression results can be spurious. Seventhly, when there is the EKC, such a relationship can be partly caused by trade effect according to pollution haven hypothesis. And the last caveat of Alstine and Neumayer (2010) is that if the EKC exists at higher levels of income the state of the environment can deteriorate in many low-income countries for many years to come.

That said, we can proceed to an empirical analysis of the impact of economic growth on harmful emissions in the EU.

3. The model

We conduct an empirical analysis of the impact of economic growth on emissions in the EU countries based on standard regression model of the EKC,[1] using our previous work on the ecological and economic consequences of global trade liberalization for developing countries (Hnatyshyn 2013) and based on the works presented in the above chapter.

According to Stern (2004), standard EKC regression model is as follows:

$$Ln(E/POP)_{k,t} = \beta_k + \gamma_t + \alpha_1 \ln (GDP/POP)_{k,t} + \alpha_2 (\ln (GDP/POP))^2_{k,t} + \varepsilon_{k,t} \quad (1)$$

where: E is emissions; POP is population; β i γ – specific parameters for countries (k) and years (t); $\varepsilon_{k,t}$ – vector of random components.

In the previous work (Hnatyshyn 2013) we use a modeł where some other indicators in addition to GDP are included. Two of them are the external trade intensity (i.e., (exports+imports)/GDP) and the amount of capital compared to labor.

An indicator of foreign trade intensity will help us identify the possible relocation of the EU polluting industries to other countries. The factor of capital abundance was important in the study conducted for countries of the world that differ significantly by this indicator. In the case of the European Union, we assume that all countries are relatively rich in capital.

Fahrani and Rejeb (2012), Shahbaz, Lean and Shahbaz Shabbir (2010) include the level of energy consumption in the country (countries) in their research. We adopt this approach, as it allows us to separately evaluate the impact of the dynamics of energy consumption on emissions. But we have to take into account that a

[1] According to Stern (2004).

separate estimation of energy consumption factor may cause the turning point to occur at a lower level of revenue compared with a model where this effect has been omitted. If we do not evaluate the energy consumption separately, its effect on emissions can be captured by GDP/POP.

We formed a model in such a way so as to take into account the potential existence of EKC through GDP per capita evaluation and by considering additional important factors: the intensity of external trade and the level of primary energy consumption. We use logarithms in the model to estimate the non-linear relationship between the variables. So far our model is presented by the following equation:

$$\mathrm{Ln}(E/POP)_{k,t} = \alpha_0 + \alpha_1 \ln(GDP/POP)_{k,t} + \alpha_2 (\ln(GDP/POP))^2_{k,t} + \\ + \alpha_3 \ln(T)_{k,t} + \alpha_4 \ln(EC/POP)_{k,t} + \varepsilon_{k,t} \quad (2)$$

where: T – international trade intensity; T = (EXP+IMP)/GDP where: EXP – export, IMP – import; EC/POP – energy consumption per capita; α_0 – specific parameters for countries and years.

The turning point income (TP) when emissions reach their maximum can be determined on the basis of the model 2, the same as for the equation (1), by:

$$TP = exp\left(-\frac{\alpha_1}{2\times(\alpha_2)}\right) \quad (3)$$

If the presumption of the environmental Kuznets curve is true, the GDP per capita growth initially causes an increase in emissions but after reaching a certain level it begins to cause a decrease in emissions. That means that the sign of α_1 should be positive, and the sign of α_2 $(GDP/POP)^2$ should be negative. The expected sign of trade openness (α_3) for developed countries, which the EU countries are, should be negative, if pollution haven hypothesis holds true. That is when the polluting production is limited in the EU by environmental laws and such goods are imported from other countries where there is a lax environmental regulation. The sign of α_4 (primary energy consumption) should be positive. We believe that economic activity stimulates growth of energy consumption, which increases CO_2 emissions.

4. Description of data and data sources

We conduct an empirical study for 28 European Union countries: Austria, Belgium, Denmark, Finland, France, Greece, Spain, the Netherlands, Ireland, Luxembourg, Germany, Portugal, Sweden, the United Kingdom, Italy, Cyprus, the Czech

Republic, Estonia, Lithuania, Latvia, Malta, Poland, Slovakia, Slovenia, Hungary, Croatia, Bulgaria and Romania.

In order to conduct the empirical research, it is necessary to take into account the type of pollution which has the following characteristics: it is closely connected with economic activity, it causes significant damage to the environment, there are emissions reduction technologies for it, there is available data on it. For our research we use data on carbon dioxide (CO_2) and sulfur oxides (SO_x) emissions in the years of 1990−2013.

EEA (2014) assessed costs of air pollution caused by European industrial companies. In Table 1 the estimated damage costs aggregated by groups of air pollution from European industrial facilities are presented.

Table 1. Costs of air pollution from European industrial facilities (2008–2012)

Pollutant group	**Aggregated damage cost (billion EUR, 2005 prices)**				
	2008	**2009**	**2010**	**2011**	**2012**
Main air pollutants (NH_3, NO_x, PM_{10}, SO_2, NMVOCs)	58–168	47–136	44–129	43–124	40–115
CO_2	20–82	18–73	19–76	18–74	18–73
Heavy metals (As, Cd, Cr, Hg, Ni, Pb)	0.53	0.34	0.43	0.34	0.34
Organic pollutants (benzene, dioxins and furans, PAHs)	0.22	0.11	0.17	0.22	0.10
Sum	**79–251**	**65–209**	**64–206**	**62–199**	**59–189**

Source: EEA (2014).

Carbon dioxide is the primary greenhouse gas emitted through human activities and is one of the main reasons of global warming. Carbon dioxide is a colorless, odorless gas, released mainly from fossil fuel combustion (coal, natural gas, and oil) for energy and transportation. CO_2 is also emitted through some industrial processes and land-use changes (EPA 2015). CO_2 is a pure "public bad". Its harmful effects are not limited by country borders. It is a subject to international free rider problem. The benefits of carbon dioxide emissions control are global, but individual countries receive only a small portion of these benefits, while bearing the full costs. Therefore, the political effects of economic growth on reducing emissions may be weaker than in the case of more visible and local types of pollution (Bouvier 2004).

The data on emissions of carbon dioxide were obtained from the database of EDGAR (2014). The data refer to CO_2 emission totals of fossil fuel use and industrial processes emissions.[2] Because of different country sizes in our sample in

2 Industrial processes emissions include cement production, carbonate use of limestone and dolomite,

order to estimate the panel regression we use per capita measure of CO_2 emissions. The data on population were obtained from the WB (2015). Based on these data, we constructed a graph of yearly CO_2 emissions per capita for the EU countries (Figure 1).

Figure 1 shows that the trends in carbon dioxide emissions are ambiguous. In some countries and years emissions decline and in other countries and years vice versa. In many countries CO_2 emissions remain more or less on the same level. The highest line represents Luxemburg. The reason is that it is a small country, where a considerable part of the population are commuters. Nevertheless it will not bias the results of the model (equation 2) as far as GDP and energy consumption are also measured per capita and international trade intensity is a relative term. Black dots represent average CO_2 emissions in member states of the EU. The black straight line with bullets shows the trend of average CO_2 emissions. The trend is slightly declining. Carbon dioxide emissions for Poland are marked by the dashed line.

non-energy use of fuels and other combustion. Short-cycle biomass burning (such as agricultural waste burning) and large-scale biomass burning (such as forest fires) are excluded.

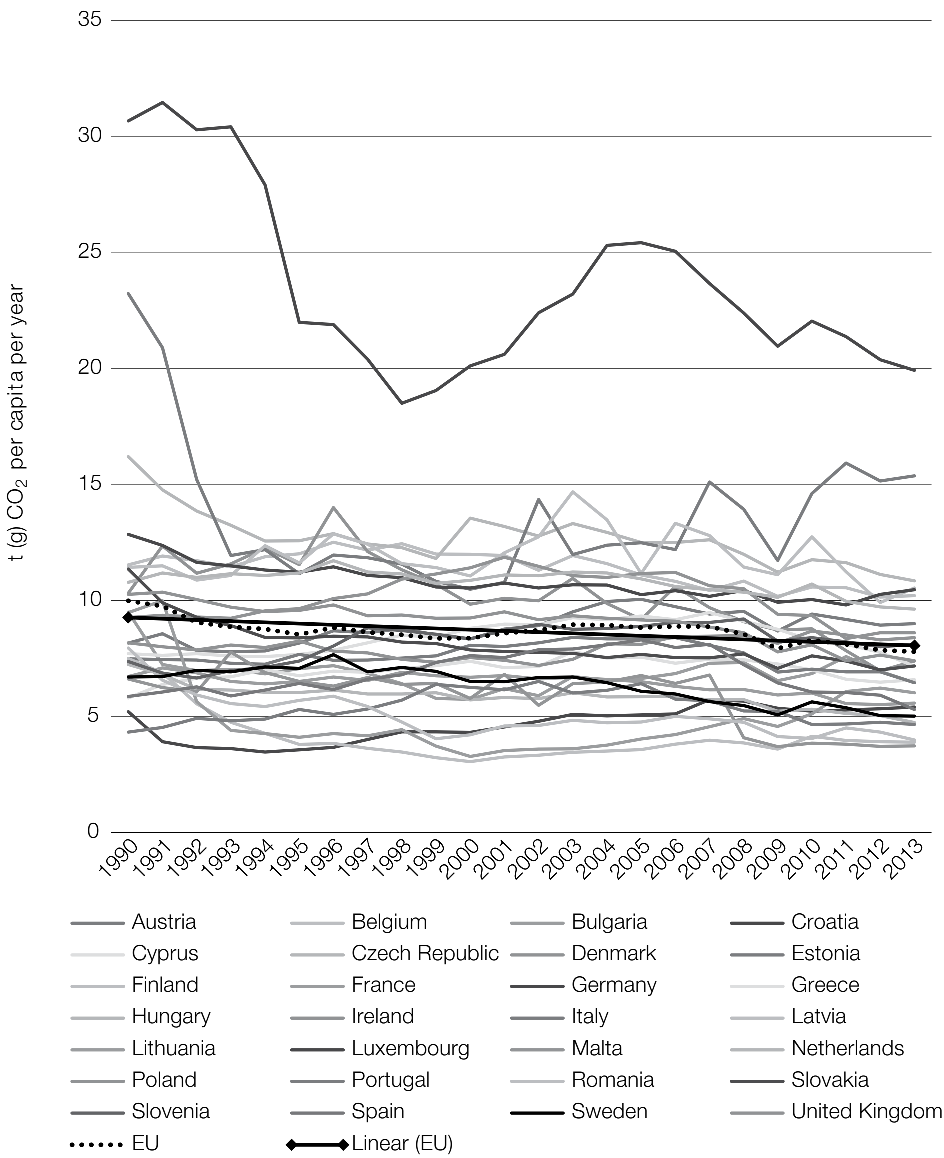

Figure 1. Per capita CO_2 emissions in the European Union countries
Source: EDGAR (2014).

To examine the changes in CO_2 emissions in the EU countries more precisely we calculated the total change in CO_2 emissions.[3] The results of the calculations are shown in Figure 2. The tendency is ambiguous. After growth in 2000−2003, emissions of CO_2 tend to decrease from 2004 on with the exception of 2006 and 2010.

[3] Emissions of the 28 EU countries in this year minus emissions in the previous year.

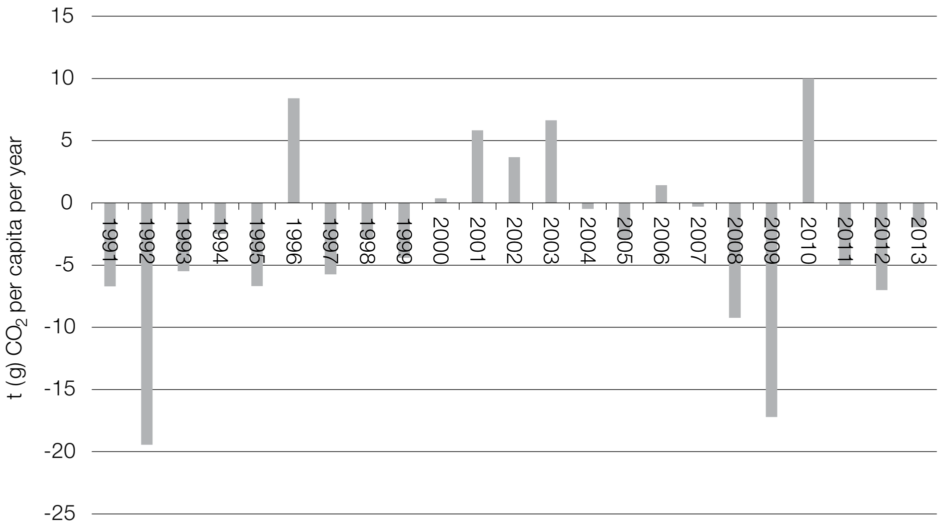

Figure 2. Total change in CO_2 emissions in the EU countries

Source: own calculations based on EDGAR (2014).

Data on emissions of sulfur oxides (SO_x) was obtained from the EMEP (2015). Among the oxides of sulfur the most commonly used gas in studies is sulfur dioxide (SO_2). Emissions causing high concentrations of SO_2 usually lead to the formation of other SO_x. SO_2 can react with other compounds in the atmosphere to form small particles. The biggest source of SO_2 emissions is combustion of fossil fuels in power plants (73%) and other industrial plants (20%). Smaller sources of SO_2 emissions include industrial processes, such as extracting metal from ore, and combustion of fuels containing large amounts of sulfur by locomotives, large ships and off-road equipment. SO_2 causes numerous side effects on the respiratory system and is a source of acid rain (EPA 2015). SO_x is a less global pollutant, than CO_2. It has both transnational and local impact and has both remote in time and immediate health effects. According to the theory, local immediate impact should speed up the EKC turning point of SO_x emissions compared to CO_2.

The data on GDP and the share of imports and exports in GDP were obtained from the WB (2015).

Data on the primary energy consumption were obtained from the international energy statistics of the EIA (2015). Figure 3 exhibits the dynamics of energy consumption in the EU countries (excluding Luxembourg for better visualization). Poland's energy consumption is marked by a dashed line and the average primary energy consumption in 28 EU countries – by a dotted line. The solid line with bullets shows the trend of the average primary energy consumption. The trend is slightly increasing, so far the primary energy consumption in the EU is increasing. In the study we do not distinguish between renewable and non-renewable energy or energy consumption being more or less polluting. What we do assess is the overall impact of the level of primary energy consumption on CO_2 and SO_x emissions.

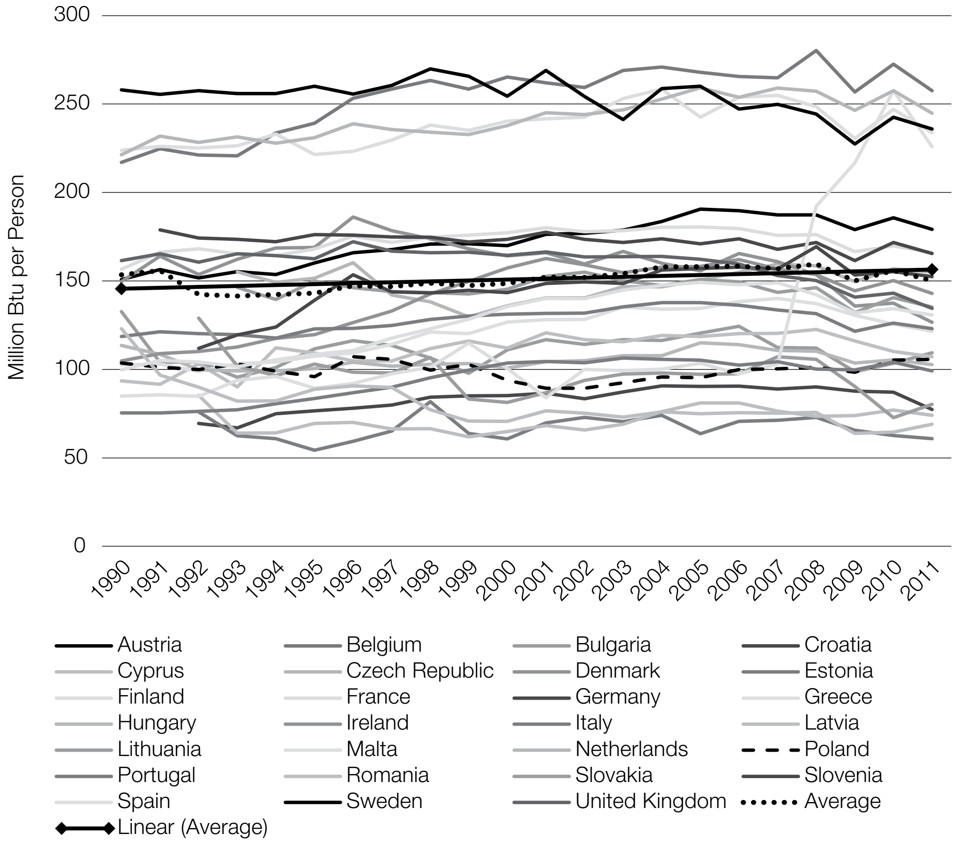

Figure 3. Primary energy consumption in the EU countries

Source: EIA (2015).

5. The model estimation

The main objective of our study is to examine whether there is a causal relationships between GDP per capita, GDP per capita squared, international trade intensity, energy consumption per capita and the emissions (CO_2 and SO_x) in 28 EU countries. The analyzed time period is 1990-2013. We use a logarithmic panel data regression model as indicated in Equation 2 in chapter 3. The estimation was carried out using the EViews program.

When country-specific effects are correlated with the explanatory (independent) variables, a random effects model cannot be estimated consistently. Using panel data for countries it is difficult to avoid this. So far, Stern (2004) suggests using fixed effects.

We have completed the testing for fixed effects. For this case we used redundant fixed effects test. It tests the joint significance of the fixed effects estimates in least squares specifications (EViews 9 User's Guide 2015). The null hypothesis is that the cross-section fixed effects are redundant. The outputs of the test for two equations are presented in the tables below.

Table 2. Redundant fixed effects test for the equation were CO_2 is the dependent variable

Test cross-section fixed effects			
Effects Test	**Statistic**	**d.f.**	**Prob.**
Cross-section F	280.836531	(27,556)	0.0000

Source: own calculations.

Table 3. Redundant fixed effects test for the equation were SO_x is the dependent variable

Test cross-section fixed effects			
Effects Test	**Statistic**	**d.f.**	**Prob.**
Cross-section F	126.175358	(27,527)	0.0000

Source: own calculations.

The results of the test strongly reject the hypothesis that cross-section fixed effects are redundant.

To decide between fixed and random effects we ran the Hausman test. The null hypothesis of the test is that random effects are better than fixed, i.e. random effects (the unique errors) are uncorrelated with explanatory variables. To perform the test we estimated a model for CO_2 and SO_2 using random effects and then performed the Hausman Test. In the Table 4 below we provide the test statistic and a summary of the results for the model for CO_2. According to the test results, the probability of the hypothesis that random effects are better than fixed is smaller than 0.05. This means that we reject this hypothesis.

Table 4. The Hausman Test of the model for CO_2

Correlated Random Effects − Hausman Test Test cross-section random effects			
Test Summary	**Chi-Sq. Statistic**	**Chi-Sq. d.f.**	**Prob.**
Cross-section random	15.955365	4	0.0031

Source: own calculations.

We performed the same test for SO_x and got the same result: that the null hypothesis is not valid. The results of the test for the model for SO_x are presented in the Table 5. The test results show that random effects are not suitable in our case.

Table 5. The Hausman Test of the model for SO_x

Correlated Random Effects - Hausman Test Test cross-section random effects			
Test Summary	**Chi-Sq. Statistic**	**Chi-Sq. d.f.**	**Prob.**
Cross-section random	64.101442	4	0.0000

Source: own calculations.

Next we applied the Breusch-Pagan LM test to test the model for the heteroscedasticity. The cross-section dependence test that is available in Eviews offers, in addition to Breusch-Pagan LM test, the following tests: Pesaran Scaled LM, Pesaran CD and Baltagi, Feng, and Kao Bias-corrected Scaled LM. The results of the tests are presented below and they strongly reject the null hypothesis of homoscedasticity.

Table 6. Cross-section dependence test (CO_2)

Residual Cross-Section Dependence Test
Null hypothesis: No cross-section dependence (correlation)
Periods included: 22
Cross-sections included: 28
Total panel (unbalanced) observations: 588

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	1953.580	378	0.0000
Pesaran scaled LM	56.28493		0.0000
Bias-corrected scaled LM	55.61827		0.0000
Pesaran CD	7.617314		0.0000

Source: own calculations.

Table 7. Cross-section dependence test (SO_x)

Residual Cross-Section Dependence Test
Null hypothesis: No cross-section dependence (correlation)
Periods included: 22
Cross-sections included: 28
Total panel (unbalanced) observations: 559

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	2116.740	378	0.0000
Pesaran scaled LM	62.21902		0.0000
Bias-corrected scaled LM	61.55235		0.0000
Pesaran CD	12.58206		0.0000

Source: own calculations.

The results of the tests show that we have heteroskedastic, correlated error structure and autocorrelation structure. Not being able to use cross-section SUR to correct for heteroskedasticity because of the insufficient number of observations (number of periods must equal or exceed the number of Pool cross-section members) we used cross section weights to estimate a feasible GLS specification assuming the presence of cross-section heteroscedasticity. The weights are estimated in the preliminary regression with equal weights and then used in the second round in weighted least squares. They allow for a different variance for each country (EViews 9 User's Guide 2015).

Based on the above diagnostics results an estimation of the model was carried out using cross-section fixed effect specification of Pooled Estimated Generalised Least Squares. The results of the estimation of the model for CO_2 are presented in Table 8.

Table 8. Estimation results of the model for CO_2

Dependent variable: Ln(CO_2/POP)				
Independent variables	**Coefficient**	**Standard error**	**t-Statistic**	**Probability**
C (constanta)	-14.31332	1.005489	-14.23518	0.0000
Ln(GDP/POP)	1.422342	0.196922	7.222862	0.0000
(Ln(GDP/POP))2	-0.079193	0.010473	-7.561671	0.0000
Ln(EC/POP)	0.723154	0.041140	17.57809	0.0000
Ln(T)	-0.080735	0.020460	-3.946000	0.0001
Years:	1990-2013			
Method:	Pooled EGLS (Cross-section weights)			
Total observations:	588			
Adjusted R-squared:	0.958811			
Durbin-Watson statistics:	0.506525			

Source: own calculations.

Based on the results of the model estimation we estimate the turning point of the EKC for each kind of pollution. The turning point for CO_2 is therefore:

$$TP_{CO2} = exp\left(-\frac{1.422342}{2\times(-0.079193)}\right) = 7{,}943.983888 \text{ USD}^{4} \quad (3)$$

This is rather a low level of income for the group of EU countries, as the average income per person in 2013 in the EU was 26,688.08594 USD[5]. That

[4] Average annual income per person in constant 2005 USD.
[5] In constant 2005 USD, World Bank Development Indicators.

means that the EU has already passed the turning point of the EKC. Among the EU member states at the beginning of our sample (in 1990) 18 countries have reached the turning point level of income, determined by us, while in the last year of our sample (in 2013) already 26 countries have passed the turning point level of income with only Romania and Bulgaria being left behind. Poland reached this level of per capita income in 2005–2006. However, CO_2 emissions in this country are still rising. The dependence of Polish energy sector on coal may be the reason.

According to the results of the model estimation, the increase in primary energy consumption (EC/POP) increases CO_2 emissions. This result is logical due to the fact that a large share of carbon dioxide is emitted in the process of primary energy consumption. The effect of international trade intensification is not so definite. Theoretically, external trade can increase the level of pollution, decrease it or leave unchanged (Hnatyshyn 2013). However, for developed countries, according to the pollution haven hypothesis, external trade should reduce pollution. The results of the model evaluation for CO_2 emissions in the EU countries confirm the possible existence of pollution havens. The variable T has a negative impact on emissions and this is an indirect evidence of polluting production migration from the EU to less developed countries.

The results of the model estimation for SO_x are presented in Table 9.

Table 9. Estimation results of the model for SO_x

Dependent variable: Ln(SO_x/POP)

Independent variables	Coefficient	Standard error	t-Statistic	Probability
C (constanta)	-26.87865	4.000442	-6.718921	0.0000
Ln(GDP/POP)	9.713423	0.781414	12.43057	0.0000
(Ln(GDP/POP))2	-0.631985	0.043098	-14.66396	0.0000
Ln(EC/POP)	0.790121	0.158644	4.980477	0.0000
Ln(T)	-0.277140	0.116989	-2.368943	0.0182

Years:	1990-2013
Method:	Pooled EGLS (Cross-section weights)
Total observations:	559
Adjusted R-squared:	0.930358
Durbin-Watson statistics:	0.320175

Source: own calculations.

According to the estimation, the significance of international trade intensity for SO_x is 0.0182. This means that we can, with some degree of certainty, determine the impact of variable T on SO_x emissions. In our case international trade intensification reduces SO_x emissions, as it does CO_2 emissions. An increase in primary energy consumption per capita increases emissions of sulfur oxides as well as in the case of CO_2.

The turning point for SO_x is:

$$TP_{SOx} = exp\left(-\frac{9.713423}{2\times(-0.631985)}\right) = 2{,}175.145148 \text{ USD}^6 \quad (5)$$

The turning point for SO_x is four times lower than for CO_2. The reduction of SO_x emissions started much earlier than those of CO_2. This means that the EU economic growth causes a more significant increase in the demand for reducing SO_x emissions.

Summing up, the results of the model estimation confirm the existence of the EKC for the two examined types of pollution. An increase in energy consumption for both types of pollution increases emissions. This means that the growth of energy consumption is in most cases achieved not from clean energy sources. The intensification of external trade reduces emissions of the studied pollutants. This fact allows us to assume the existence of polluting industries migration abroad.

6. Conclusions

In the study we verified the environmental Kuznets curve hypothesis, the pollution haven hypothesis and evaluated primary energy consumption impact on emissions. The study was conducted for 28 countries of the European Union.

Based on the results of the study we can say that for the countries of the European Union there is an inverted U relationship between economic growth and emissions for both pollutants examined. The turning point of the EKC for carbon dioxide (CO_2) is four times higher than that for oxides of sulfur (SO_x). These results indicate that along with economic growth the demand for a clean local environment grows first and the demand for a global environment improvement grows only later. In contrast to SO_x, CO_2 emissions are the most global type of pollution which causes no local or short-term damage. Nevertheless, the level of income corresponding to the EKC turning point even for CO_2 was achieved in most EU countries in the years preceding the sample.

The pollution haven hypothesis was tested through international trade intensity impact on emissions. Intensification of external trade reduces CO_2 and SO_x emissions. This is a potential evidence of polluting industries emitting these gases relocation abroad to countries beyond the EU.

Primary energy consumption in the EU countries continues to grow. Such a trend is dangerous because of the statistically significant positive effect of primary

[6] Average annual income per person in constant 2005 USD.

energy consumption on the emissions of both pollutants. The energy sector in Europe is still very dependent on fossil fuels. The problem of reconciling the interests of the economic growth (which is still based on energy consumption growth) and of the natural environment remains unsolved.

The EKC existence identification is only the basic level of understanding the impact of economic development on the natural environment. Future studies should also include an analysis of changes in the structure of exports and imports of EU countries to finally confirm or reject the hypothesis of polluting industries migration from the EU to less developed countries. Other forms of environmental degradation should also be taken into account.

References

Bouvier, Rachel A. 2004. *Air Pollution and Per Capita Income: A Disaggregation of the Effects of Scale, Sectoral Composition, and Technological Change*. Political Economy and Research Institute, University of Massachusetts, Amherst, Working Paper Series no 84.

Cole, Matthew A. 2004. "Trade, the pollution haven hypothesis and the Environmental Kuznets Curve: examining the linkages." *Ecological Economics* 48 (1): 71−81.

Costs of air pollution from European industrial facilities 2008–2012 − an updated assessment. 2014. EEA Technical report no 20. Luxembourg: EEA.

Dasgupta, Susmita, Benoit Laplante, Hua Wang and David Wheeler. 2002. "Confronting the Environmental Kuznets Curve." *Journal of Economic Perspectives* 16 (1): 147−168.

Dinda, Soumyananda. 2004. "Environmental Kuznets Curve hypothesis: a survey." *Ecological Economics* 49 (4): 431−455.

Farhani, Sahbi and Jaleleddine Ben Rejeb. 2012. "Energy consumption, economic growth and co2 emissions: evidence from panel data for MENA region." *International Journal of Energy Economics and Policy* 2 (2): 71−81.

Grossman, Gene M. and Alan B. Krueger. 1993. "Environmental impact of a North American Free Trade Agreement." In: *The US-Mexico Free Trade Agreement*, ed. Peter M. Garber, 13−56. Cambridge, MA−London: The MIT Press.

Hnatyshyn, Mariya. 2013. *Ekologo-ekonomichni naslidki liberalizatsii cvitovoi torgivli dlia krain, shcho rozviviutsia*. Lviv: Lvivskyi Natsionalnyi Universytet imieni Ivana Franka.

Kaika, Dimitra and Efthimios Zervas. 2011. "Searching for an Environmental Kuznets Curve (EKC)-pattern for CO2 emissions." In: *Recent Researches in Energy, Environment and Landscape Architecture. Proceedings of the 7th IASME/WSEAS Conference on Energy, Environment, Ecosystems and Sustainable Development. Proceeding of the 4th IASME/WSEAS International Conference on Landscape Architecture*, ed. Gregoire Thomas *et al*., 19−24. Angers: WSEAS.

Olivier, Jos G., Greet Janssens-Maenhout, Marilena Muntean and Jeroen A.H.W. Peters. 2014. *Trends in Global CO2 Emissions: 2014 Report*. The Hague: PBL Netherlands Environmental Assessment Agency.

Omay, Rabia Eco. 2013. "The relationship between environment and income: regression spline approach." *International Journal of Energy Economics and Policy*" 3: 52−61.

Shahbaz, Muhammad, Hooi Hooi Lean and Muhammad Shahbaz Shabbir. 2010. *Environmental Kuznets curve and the Role of Energy Consumption in Pakistan*. Development Research Papers no 10 (5).

Stern, David I. 2004. "The rise and fall of the environmental Kuznets curve." *World Development* 32 (8): 1419−1439.

Van Alstine, James and Eric Neumayer. 2010. "The environmental Kuznets curve." In: *Hanbook on Trade and the Environment*, ed. Kevin P. Gallagher, 49−59. Cheltenham: Edward Elgar.

Databases

EDGAR database. 2014. (16 December). http://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts1990-2013, (accessed: 15.09.2015).
EIA (International Energy Statistics). http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=44&pid=45&aid=2&cid=LU,&syid=1980&eyid=2011&unit=MBTUPP (accessed: 15.09.2015).
EPA. Sulfur Dioxide. http://www.epa.gov/airquality/sulfurdioxide/ (accessed: 15.09.2015).
WebDab, EMEP database. http://www.ceip.at/ms/ceip_home1/ceip_home/webdab_emepdatabase (accessed: 15.09.2015). World Development Indicators of the World Bank, available from: http://data.worldbank.org, (cited September 2015).