An Empirical Analysis of the Interaction Between Economic Performance and Environmental Quality

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Abstract

In this study the Environmental Kuznets Curve is tested. It is a relationship between economic performance and environmental quality. This research solves the main problem that is connected with the EKC theory that is endogeneity of the main variables. Also the basic model is expanded to the extent that technology and Kyoto Protocol effects on CO_2 gas emission are captured. The study is conducted on the panel data of 114 countries for the period of 1993-2007. Empirical testing procedure consisted of three model specifications (time FEs, country and time FEs, linear country and time FEs) and two estimation techniques (OLS and 2SLS). As the result, through 2SLS method evidence for inverted U-shape Environmental Kuznets Curve is obtained. In addition study shows that exploration of the EKC can be improved in the sphere of technological progress inclusion into the model. The Kyoto Protocol impact is estimated to be almost marginally significant.

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1. *Introduction*

In recent time the problem of global warming occupied minds of the public and was a top debate topic for many people all over the world. Scientists are in the continuous process of search for the causes, consequences and possible strategies to overcome climate changes. Economists are not left out from the discussion because economic activity creates the most part of the green house gases (GHG) emission in the world. Increases in fossil fuel burning, agriculture exercising, population growth, mining, industrial production processes, and deforestation are the main factors that led to climate change on the planet.

According to the World Development Indicators (2011) website database statistics, gross CO_2 emission increases over the time. Even though the rate of accumulation of this GHG is slowing down in the last years the total volume is growing constantly. To be more precise, the level of CO_2 emission has grown 50% from the level of year 1960. In addition, CSIRO Marine and Atmospheric Research (2011) reports on the sea level that yearly Global Mean Sea Level (GMSL) increases on average by 3.2 mm with a standard deviation of 0.4 mm. This stable positive trend in air pollution followed by climate change can lead to serious consequences to all mankind.

Environmental Kuznets Curve (EKC) is an inverted U-shaped relationship between income and CO_2 emission, while taking into account environmental policies, technology and sector composition. This concept was introduced by Grossman and Krueger (1991) in their work “Environmental Impacts of a North-American Free Trade Agreement” and later it was developed in their work “Economic Growth and the Environment” that was completely dedicated to estimation of the EKC curve for various pollutants.

The exploration of the Environmental Kuznets Curve started a long time ago. At first, a vast amount of the literature on this topic mainly concentrated on the detection of the inverted U-shaped relationship between pollution and income. This relationship pattern belongs to the class of Kuznets Curves, and since it captured environmental aspects of the economic activity, the specification “environmental” was added. Authors like Brock and Taylor (2010), Maradan and Vassiliev (2005), Heil and Wodon (2000), Azomahou et al.(2005), Whalley and Yuan (2009), Grundewald and Martínez-Zarozoso (2009) focused their attention primarily on the empirical research of connection between pollution and income and on specific aspects of their relationship.

Attention of other researchers was directed towards the theoretical explanation of the Environmental Kuznets Curve and its driving forces. They mainly expanded the economic growth base models by introducing pollution into the models. Smulders et al. (2010), Harris (2008), Nakada (2004), Carraro (1998) and Rezay et al. (2010) gave a substantial and comprehensive theoretical explanation for the Environmental Kuznets Curve relationship. Both groups of authors experienced weaknesses from the point of view of the econometrics. In particular, those authors did not pay attention to problem of endogeneity in main variables and as the result they did not apply corresponding econometric techniques.

After careful consideration of the existing literature, I will follow the idea of Smulders et al. (2010) and in the current analysis I will use the Schumpeterian endogenous growth model approach that is expanded in extent to account for GHG emission and for the factors causing the climate change. The technological impact on the relationship will be caught in the model as well by the help of proxy variable. In addition, I will check the validity and the effectiveness of the Kyoto Protocol, a climate change mitigation policy. Therefore, a dummy variable for countries that ratified the agreement will be added to the equation. Since the first stage of the agreement is up to end, it would be useful and interesting to know whether the goals set are achieved or not. Moreover, in this work I will overcome the problem of endogeneity that is present in the EKC. The actual proposition to solve the problem of endogeneity was introduced in the theoretical work of Smulders, Bretschger and Egli (2010).

In other words, I will follow the direction identified in the paper and implement suggestions in practice.

The study will cover dynamics of the climate change and economic activity relationship during the last decade. For its implementation a panel data set across 114 countries will be used. The main sources of the data are international development institutions and conventions/agreements like the World Bank, the Intergovernmental Panel on Climate Change, and the United Nation Framework Convention on Climate Change. Those will provide the data for the CO_2 emission and the main indicators of sustainable development. It is important to emphasize that the choice of CO_2 was not accidental. Inclusion of the carbon dioxide into regression will allow to connect the results with the Kyoto Protocol because it is one of the six green house gases under restriction. CO_2 is also attractive from the point of availability of the data. Furthermore, this gas is the most common byproduct of any anthropogenic economic activity.

As the result of econometric analysis, I obtained evidence for inverse U-shaped Environmental Kuznets Curve. This finding tells that CO_2 gas emission will grow up till the point of the highest income where, according to the theory of the EKC, the relationship between economic performance and environmental quality will start to be negative. Regarding, counting for technology and the Kyoto Protocol, coefficients does not have enough explanatory power but there are several logical reasons for it. Overall, the results are credible since the chosen econometric technique is effective in fight against endogeneity. Panel data usage also facilitated the analysis by capturing unobserved country and time specific effects as well as it helped in reducing collinearity among variables.

The rest of the paper will go as follows. The next section will present the main literature on the topic and trends of the environmental theory development. After thorough consideration, the theoretical basis for the current empirical study will be chosen. Section 3 and 4 will contain data description and modeling. In the fifth section empirical estimation and results will be described. The final part will conclude on the paper and provide insights and ideas for further research.

2. *Literature Review*

In this section, I provide a short overview of theoretical and empirical works on the Environmental Kuznets Curve relationship. The main focus of this part is the demonstration of theory evolution as well as specification of up-to-date theoretical basis for the empirical testing in the current study. Historical overview will show all the shortcomings of the previous econometric techniques and justify all innovations that will be applied in current study.

The first work on the EKC was done by two economists Grossman and Krueger (1991). They observed patterns in the relationship between emission of the different GHGs and the economic welfare. The authors empirically proved existence of the inverted U-shaped for the most types of gases-polluters. Their work induced a boom in research of the new type of theory. The importance of research in this sphere was also justified by the character of the problem that lied in the heart of the new concept. Its relation to the global warming and climate change is crucial and keeps potential hazard to humankind; therefore, people started to realize it, develop theory and propose possible resolutions in order to ameliorate the present situation. The main factor behind the environmental change relates closely to the emission of GHG, byproduct of industrial activity.

According to Carraro (1998) environmental economics initially started to develop from the empirical observations of interaction between environmental and economic indicators. In order to explain the main trends observed, a new economic branch of theory started to develop. First, economists used means of supply and demand mechanism for pollution in order to describe and explain the Environmental Kuznets Curve pattern. Even though this line of theory can explain the relationship described by EKC well, it was not complete in a sense that it could not explain deviations of income-GHG emission relationship from the inverted U-shape pattern.

In particular, Maradan and Vassiliev (2005) utilize this approach to understand the impact of economic growth on the change of marginal abatement costs. They address this issue by the construction of non-parametric piecewise-linear production frontier using a cross-country data set of 76 countries. The year of observation is 1985 and mainly all the pool of countries is divided into two parts of developed and developing countries. In addition, they estimate shadow prices and efficiency score for CO_2 emission across countries. Moreover, they specify such a model that includes consumption, capital stock, labor force and arable lands.

The main finding of the paper goes in the accordance with EKC theory of emergence, i.e. costs of abatement decrease with the income growth. It can be interpreted in a way that it is cheaper for developed countries to implement pollution mitigation. Even though valid and credible results are obtained, the authors point out necessity for further extension of their work. Technological diversification among the countries, panel data estimation of EKC, non-static nature of production frontier leaves room for further research. Moreover, they accept as a possibilty that EKC inverted U-shape pattern is not stable. Therefore, further research in this direction could be also important.

Azomahou et al. (2005) conduct a study of defining the shape of the EKC inspired by the uncertainty of the CO_2 emission and income relationship characteristics. They are innovative in a sense that they do not include additional variables emphasizing that their interest is only in the functional form of the relation between income and pollution. They apply nonparametric analysis for panel data for the time period of 1960-1996. As a result they got monotonically increasing relationship between estimated parameters.

The finding implies that the problem of pollution and global climate change cannot be solved by simple increase in income growth, since the latter does not have enough power to reverse the trend of increasing GHG emission. Consequently, international joint action that will cover not only developed but also developing countries should be undertaken. In addition to the main results emphasized by the authors, it is worth noting that one of the basic assumptions on the income exogeneity used widely previously, was proven to be irrelevant, i.e. new phase of environmental economics was up to start.

At that stage environmental economics absorbed innovations of related economic spheres like economic geography, industrial organization and developmental economics. After incorporation with the latter, growth and environment issues captured the minds of many environmental economists. But this wave of interest towards the problem was in terms of macroeconomic theory. At first, analysis considered of EKC did not allow for endogeneity of technology or income growth at the same time. Therefore, mainly the Solow growth model and growth accounting trend were used in environmental economics.

Following the new tendency, another group of authors conducted studies about the income growth and GHG emission relationship. Harris (2008) expanded the simple growth accounting model by adding in it several ecological parameters. In particular, basic macroeconomic equation for GDP was transformed and differentiation between private and government investments in energy conserving and energy intensive productions was taken into account. In the author's opinion, this way of thinking about the issue will help to find particular solutions for the increasing problem of climate change. He considered several possible scenarios for global economic development and drew conclusion that growth will help to overcome problems with GHG emission. However, this progress should be regulated by the government in a way to change technology towards a pollution-free one. In his opinion, this attempt will require huge transformations in the infrastructure and those changes should be rapid in order not to worsen environmental problems further. The author supported the ideas of "green" taxes and monetary policy introduction as well as the development of influential and powerful governmental body to regulate environmental policies.

Authors like Brock and Taylor (2010) aimed to extend simple model in the direction of environmental economics. This basic model was Solow model and after incorporation of technological process in abatement they renamed it as Green Solow model. According to this theoretical modeling the Environmental Kuznets Curve pattern occurs as a residual in the result of growth path convergence.

Within the established framework the actual data was tested. They chose a time period from 1960 to 1998 with the sole purpose to escape from possible deviation connected with the Kyoto Protocol creation. The data was divided into 5 samples depending on the purpose of the estimation. The author utilized two types of model specifications: The first one captured only relation between economic growth and CO_2 gas emission per capita and the second one additionally estimated the effects of average investment to GDP ratio and average population growth. Their main result proved the solid explanatory power of the Solow model in the process of EKC pattern determination.

Another attempt to integrate the relationship between pollution and income into the macroeconomic growth model was done by Rezay et al. (2010). They approached GHG emission as negative externality caused by market inefficiency that only can be corrected through Pareto improvement. In this case, increase in mitigation investments and decrease in accumulation of the capital are perceived to be this improvement solution. In order to prove the hypothesis they combined the Ramsey-Cass-Koopmans model with mitigation investment. The results of the calibration for the constructed model implied that achievement of the desirable result demands a lot of transformation in the technology used. The results of their research paper coincide with the ones of Harris (2008). In both cases, the huge costs of changing lifestyles are realized as the price of cleaner environment achievement.

The most recent stage of income-GHG emission relationship research, the third stage, is marked by simultaneous endogeneity of technology and economic growth in the model. Good example of theoretical paper was written by Smulders et al. (2010) and it is based on the Schumpeterian endogenous growth model. By modeling pollution change accompanied with evolution of the general purpose technology and its impact on the income growth authors gave another theoretical explanation for EKC inverted U-shape pattern. Another novel contribution introduced in the modeling framework was differentiation between pollution-using and pollution-saving technologies.

The main idea of the paper stems from the authors' perception of innovation process induced through the policy changes. Since they introduced the endogeneity of the technological innovation process into the model and accepted endogeneity of the income growth, i.e. new trend in understanding EKC occured. While their analysis established to include the process of the innovation and emphasized the importance of exogenous policies like the Kyoto Protocol, the potential for endogeneity of the variables raises concerns about the validity of the empirical estimation of the GHG-emission and income relationship with changes in technology not being exogenous anymore. In other words, the analysis in Smulders et al. (2010) revealed the problem of endogeneity, and resolution of this problem is essential to obtain efficient parameters of the EKC relationship. A possible solution proposed is system estimation that represents an unexplored aspect of the EKC empirics.

The overview of the literature discussed up until now was covering theoretical background related to GHG-emission and income relationship in the sphere of environmental economics. The other set of the literature provides the empirical base for analysis and expands possibilities for examining the EKC relationship in new interesting ways. In particular, they are Whalley and Yuan (2009) who explores expansion of the financial sector with stable increase in GHG emissions and growth of temperature and climate change. They argued that financial innovations in the insurance sector will take place under the scenario of a continuous environmental change. Since their paper was one of the first discussions on the border of environmental economics and finance, further research in this sphere promises to be very productive and necessary.

Since the issue I intend to examine in my thesis has a global character it is important to pay attention to the effectiveness of political actions aimed at pollution decrease. One of those international policies is the Kyoto Protocol. It has been more than five years of continuous observance of this convention and the first stage of its implementation is about to end in 2012. Makarenko (2007) in his article described each and every stage of the protocol's history and its highlights. He emphasized its economical nature; therefore, from the side of economics several works were logically dedicated to the exploration of effectiveness and validity of the protocol.

One of the recent papers by Grundewald and Martínez-Zarozoso (2009) reported ambiguous results for the inverted U-shaped EKC. The analysis used a pooled data set of 123 countries for a period of 35 years. They employed a theoretical model called STRIPAT that refers to a stochastic environmental impact model initially developed by Dietz and Rosa. However, the main distinctive feature of their work lies in the investigation of the effectiveness of the Kyoto Protocol. The authors' empirical analysis was carried out by the inclusion of several dummy variables into their regression models. They also tried to capture effects of Clean Development Mechanisms (CDMs). Their finding supports positive effects of policies like CDMs and the Kyoto Protocol, i.e. implementation of the pollution restrictions indeed decreases GHG emission according to the authors. Even though, their work gives an answer on the effectiveness of the protocol it does not estimate its effect on the income growth that might also decrease, especially, for protocol ratifying countries.

In his research Nakada (2004) analyzed the impact of environmental policies on the economic growth. His main hypothesis was to test the so called "Porter Hypothesis" which states that the regulation of the environmental policy will induce technological innovations necessary to overcome pollution problem. Since firms will be punished through taxation for the usage of pollution intensive technologies by reductions in their profits they will have incentives to invest in research and development (R&D) and come up with pollution free technologies. In the author's paper, theory was derived on the basis of the simple growth model extended to intermediate good inclusion which is the transition good from the inefficient to efficient technologies. Additionally, the author found that subsidies for R&D boost growth even more than taxation.

Summarizing the literature reviewed a general picture can be formed. There are several approaches to understand GHG emission and income dependency – microeconomic based supply and demand model as well as macroeconomic growth model. The most prominent one incorporates in itself the Schumpeterian growth model and simultaneously endogenized technology and economic growth. This way of testing EKC is not well explored; therefore, it should be developed and applied empirically. Other works introduced nontrivial aspects of the relationship and discussed possible transformations climate change can bring. Some of the authors were not satisfied with the role of predictors and observers and tried to find efficient instruments to overcome the pollution problem and analyze currently undertaken measures like the Kyoto Protocol.

3. *Data Description*

In this section I will describe the data utilized in the current paper. Since the Environmental Kuznets Curve is the relationship between wealth and pollution, the gross domestic product (GDP) will be taken as the proxy for wealth and the CO_2 emission will be chosen as the main approximation for the pollution. In addition, the current research has an aim to use idea of the Schumpeterian endogenous growth model with pollution as one of the basic components of analysis, thus a technological progress variable will be constructed into regression. In the previous literature it was a tradition to proxy technology with introduction of the deterministic time trend into the model. Specifically, He and Richard (2009) used this technique in the modeling of the Environmental Kuznets Curve. This maneuver is a necessity, because there is no data available for the technical advances on the country level. However, following the other trend of Vita (2011), I consider the number of scientific and technical articles published in the country as a proxy for technological progress. In order to capture changes in growth, environment, and technology, I include other control variables, namely the number of people in the labor force, volume of energy consumption, area of arable lands, level of consumption, and level of capital formation.

The data sample in the current work combines 114 countries' annual statistics for the time period of 1993-2007. The choice of the set of countries was based on the availability of the data for the necessary set of the variables for the longest period of time possible. Similarly, to the works of Nondo (2010) and Maradan and Vasiliev (2005) the model will apply the following range of the quantitative variables:

$CO2_{it}$, the data for carbon dioxide emission per capita of country i at the time t is measured in tons of the polluting gas per person. It was obtained through the website of the U.S. Energy Information Administration (EIA), http://www.eia.doe.gov/. It is a panel data set that consists of yearly observations referring to 114 countries for the time range of 1993-2007. For its construction, the agency assumes that the emission comes from fossil fuel burning like combustion of coal, natural gas and petroleum. Small portion of this GHG that came from nonfuel use of the energy inputs was also considered in the computation process.

GDP_{it}, the data for the gross domestic product (GDP) per capita in country *i* at the time *t* is measured in the current US dollars per person. It was collected from the website of the World Development Indicators (WDI) database, http://data.worldbank.org/indicator/all. This is a panel data set that is available for the same range of the years and the same set of the countries. I chose the gross domestic product per capita in accordance with the existing empirical literature and because of its connection to the number of the people in the country. The GDP calculation contains value added by each and every resident of the country and no deduction for depreciation of assets or natural resources were done.

$SCIARTC_{it}$, the number of scientific and technical journal articles as the measurement of the technological progress in country *i* at the time *t* computed as the number of publications per person in the fields of physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences. The data comes from the WDI database website, http://data.worldbank.org/indicator/all. It is a panel data set that consists of yearly observations referring to 114 countries for the time range of 1993-2007.

LAB_{it}, the number of people in the labor force for country *i* at time *t*. The data source is WDI website database http://data.worldbank.org/indicator/all. According to the estimation method, the variable contains the number of people over the age of 15 in the economically active population across 114 countries for the time span of 14 years starting from 1993 year. Informally hired workers, homeworking participants of the market and unpaid volunteers were excluded.

$ENRG_{it}$, the volume of consumed energy in the economy of country *i* at time *t*. This variable comprises of the volume of energy before its transformation to final-use fuel. On the WDI website database http://data.worldbank.org/indicator/all the variable is available for the same sample of countries as the other variables and for the same time period.

$CONS_{it}$, the level of consumption in country *i* at time *t*. It is collected for the same time span and countries' sample as other variables and from the same data source of WDI website database http://data.worldbank.org/indicator/all. According to the agency, it is computed as the sum of the market values of all goods and services purchased in the economy of the particular country.

$CAPT_{it}$, the data for the capital formation in country *i* at time *t*. This variable is one of the country development indicators available from the WDI database website, http://data.worldbank.org/indicator/all. It determines additional investments into fixed assets and inventories in the economy. This is also a panel data set for the sample of 114 countries from the year 1993 till 2007 .

$LAND_{it}$, the area of arable lands in country *i* at time *t* measured in hectares per capita. It was obtained from the Word Development Indicators website database http://data.worldbank.org/indicator/all for 114 countries starting from the 1993 upto 2007. It can be described as lands under current cultivation and pastures. Since crops and domestic animals are also sources of the GHG gases generation and one of the assets of the economic growth, inclusion of the arable lands into regression is important for a better model specification.

Finally, it is important to define GDP, CO_2 emission volumes and technological advance as the main endogenous variables in the analysis. In addition, the vector of covariates that will specify the model precisely will consist of labor force, energy consumption, arable lands, consumption, and capital formation. All the variables are collected from reliable databases and they need no additional transformations or manipulations for the model estimation. The number of countries for which the data was obtained does not correspond to the full set of existing countries. The only explanation for the usage of this sample of countries lies in the unavailability of the data for the full set of variables for the whole range of years for the rest of the countries not included in the econometrical analysis. The time span for the research was chosen with the only purpose to consider such a time period that is long enough for acquiring meaningful results regarding the variables included as well as recent enough to be of interest.

In the next section, I discuss the econometric modeling that will be used for the empirical analysis. I will specify main variables and technique that will be applied for estimation. Also I will identify impact of the existing literature on the current model specification.

4. *Modeling*

This section will give a brief description of the model that will be estimated in the present work. This econometric model emerged out of the combination of several ideas used in the conterminous research. In particular, it combines the work of Nondo et al. (2010) that conducts empirical estimation of the relationship between the economic growth and environmental regulations; Maradan and Vassiliev (2005) that are exploring the question of marginal costs of the CO_2 emission abatement; and Smulders et al.(2010) that innovate the EKC theory with the Schumpeterian endogenous growth approach. The first work contributed to the choice of the econometric method of estimation. The second group of authors gave the idea for main variables in the model and the third helped with the introduction of endogenous technological progress.

I will start with the introduction of technological progress into the standard EKC theory that, previously, was assumed to be exogenous. This idea was developed in the paper of Smulders et al. (2010) and was based on the modification of the basic Schumpeterian endogenous growth model. They mentioned that all the variables in the EKC model are highly endogenous and the newly introduced technological progress shares the same characteristic. Indeed, the level of technology has influence on the growth of the economy and pollution. In return, growth will determine the progress and cleanliness of the environment. Therefore, according to the authors, simultaneous system estimation should be used in order to answer the problem of endogeneity as this method ensures not only consistency, but also efficiency. In particular, I follow the idea of Nondo et al. (2010) and apply in my research 2SLS or Two Least Squares estimation procedure. The model they constructed can be easily transformed for the needs of the current research; in other words, it provides valuable guidelines in construction of econometric framework.

Combining works of Smulders et al. (2010) and Maradan and Vassiliev (2005), I use the basic framework for the estimation of the inverse U-shape relationship between carbon dioxide emission and gross domestic product of the country while endogenizing technological and research advance in the country.

$$\mathrm{CO2}_{it} = \beta_0 + \beta_1 \mathrm{GDP}_{it} + \beta_2 \mathrm{GDP}_{it}^{\ 2} + \beta_3 \mathrm{SCIART}_{it} + \sum \beta_{l\mathrm{CO2}} \Omega^{\mathrm{CO2}} + u_{it} \qquad (1)$$

where,

$\mathrm{CO2}_{it}$ stands for the level of the CO_2 emission volume in country *i* at time *t*, measured in tons of CO_2 emission per capita;

GDP_{it} proxies the level of income in country *i* at time *t*; and $\mathrm{GDP}_{it}^{\ 2}$ is added to capture inverse U-shape of the Environmental Kuznets Curve, measured in US Dollars per capita;

SCIART_{it} is the volume of the scientific articles in country *i* at time *t*;

$\sum \beta_l \Omega^{\mathrm{XO2}}$ is the term that stands for the set of the exogenous covariates having influence on the change of endogenous variables;

u_{it} – is the white noise structural error term;

$i = 1,2,3,\ldots,\mathrm{N}$ and $t = 1,2,3,\ldots,\mathrm{T}$.

The sum term of exogenous explanatory variables will be specified mainly according to the work of Maradan and Vassiliev (2005); however, additional dummy variable for ratification of the Kyoto Protocol will be added due to my special interest in the evaluation of performance of the international climate change preventing actions.

$$\mathrm{CO2}_{it} = \beta_0 + \beta_1 \mathrm{GDP}_{it} + \beta_2 \mathrm{GDP}_{it}^{\ 2} + \beta_3 \mathrm{SCIART}_{it} + \beta_4 \mathrm{KYOT}_{it} + \beta_5 \mathrm{LAB}_{it}$$
$$+ \beta_6 \mathrm{ENRG}_{it} + \beta_7 \mathrm{CONS}_{it} + \beta_8 \mathrm{CAPT}_{it} + \beta_9 \mathrm{LAND}_{it} + u_{it} \qquad (2)$$

where,

KYO_{it} – is the dummy variable that takes the value of 1 if country *i* at time *t* ratified the Kyoto Protocol and 0 otherwise;

LAB_{it} – is the number of people in the labor force for country *i* at time *t*;

$ENRG_{it}$ – is the volume of consumed energy in the economy of country *i* at time *t*;

$CONS_{it}$ – is the level of consumption of country *i*'s economy at time *t*;

$CAPT_{it}$ – is the capital formation in country *i* at time *t*;

$LAND_{it}$ – is the area of the arable lands in country *i* at time *t*;

In the model GDP_{it} measures per capita positive output of the economic activity and determines the economic growth in the country. The $CO2_{it}$ emission stands as a proxy for the pollution level and captures the negative output of the economic activity. It is valuable to consider the effect of this green house gas since it produces the most out of all GHGs in the world. The $SCIART_{it}$ enriches the initial EKC model and allows estimating the effect of the technological advance on the pollution-income relationship.

One of the main assumptions in this research is about the production function of economic activity; according to it, either negative output of the CO_2 gas or the positive output of the gross domestic product is produced. Therefore, accounting for the inputs of production is essential. For that reason, variables like LAB_{it}, $ENRG_{it}$, $CAPT_{it}$, $LAND_{it}$ represent main components of the production. The $CONS_{it}$ is the complementary variable to the GDP_{it} and helps to proxy desirable output in the model. Finally, the KYO_{it} is a dummy variable that is employed for the purpose of identification of the Kyoto Protocol's effectiveness and successfulness.

In the result the expected signs for β coefficients will go as follows:

- according to the EKC theory β_1 slope parameter should be positive and β_2 should be negative in order to capture inverse U-shaped relationship between CO_2 emission and economic performance;
- β_3 is expected to be negative, since the technological and research advances are supposed to decrease pollution level in the economy;

- the sign for β_4 that captures effect of the Kyoto Protocol is anticipated to be negative because the main aim of the international environmental regulations is to decrease level of GHGs emission;
- the coefficient of β_5 should turn out in positive value as well as β_6, β_8, and β_9 since those are slope values for the variables LAB_{it}, $ENRG_{it}$, $CAPT_{it}$, and $LAND_{it}$ from the production function that contributes to increase of the CO_2 in the atmosphere;
- finally, there should be positive β_7 that will reflect positive influence of consumption in the economy on the increasing pollution level.

Estimation procedure will consist of three models and two estimation procedures. Model 1 I is based on the simple ordinary least squares (OLS) procedure assuming no difference from country to country and expecting the common βs, slope coefficients. In the second model, I will count for time specific effects in the regression by estimation of period fixed effects (FEs). The next one, Model 3 will allow not only for time specific effects, but also for country specific effects. In Model 4, I want to estimate the linear relationship between CO2 emission and GDP controlling for country and time specific effects with the help of fixed effects (FE). However, in order to obtain credible results corresponding econometric method should be chosen. Since in the base model I face the problem of endogeneity among of the main variables, like GPD, CO_2 emission and number of scientific articles, I will employ 2SLS or Two Stage Least Squares procedure. This would be my last model to estimate and it will be combined with period and cross section fixed effects those will count for the differences across countries and time as well as it will correct my econometric relationship for endogeneity. Moreover, it will be easier to implement this analysis due to availability of the panel data; it is advantage of the panel data set that in 2SLS lagged estimators of the endogenous variables can be used as instrumental variables (IVs).

Concluding on the modeling description, in this study additional covariates were specified according to the work of Maradan and Vassiliev (2005). As well, following the research of Smulders et al. (2010), I will capture effect of the technology, which is consistent with idea of Schumpeterian endogenous growth model with pollution. I will also examine effect of international environmental regulation, the Kyoto Protocol, with the help of dummy variable. In other words, the current work combines an outcome of the contribution of the Schumpeterian endogenous theory into the traditional EKC theory, goal to estimate the effect of the Kyoto Protocol and a new econometrical approach for the estimation of the environment quality and income relationship.

In the next section, I discuss the estimation results. I provide analysis and overall evaluation of the econometric model outcome and explain it with the help of existing theory.

5. *Estimation Results Discussion*

This section will discuss in details methods of econometric analysis and obtained results. Another aim of this section is evaluation and examination of the different estimation procedures through which the results were obtained. During the modeling specification discussion, five different ways to test the EKC relationship were defined. In particular, there will be three different models estimated using two econometric techniques.Through the comparison of those it will be possible to define the one that gives more credible and consistent results. At first, Model 1 will provide estimation of the pooled regression with the simple OLS technique. It will not count for any specific country or time effects assuming no unobserved heterogeneity from country to country and common β coefficients. However, it is the case that observations contain unobserved heterogeneity across time and countries; therefore, OLS results will be biased in the current research. Based on this reasoning, the next two models will be advanced in the sense that it will be panel data regression that at first will be estimated taking into account time specific effects and then country and time specific effect together. The fourth model will be important for the discussion of the inverse U-shape of the Environmental Kuznets Curve. Finally, after review of all the problems occurred during usage of the pooled and panel data OLS estimation, advanced econometric method will be applied. It will deal not only with technical problems but also with main problem of the endogeneity in the variables.

The Table 1 summarizes the results of all estimated models. It provides β coefficients and standard errors for each of them, and by the number of asterisks I identify significance level of the obtained result. In addition, in the table the outcome for main variables marked with the bold text. For Model 1 the unbiasedness of the OLS results stays on the assumption of $\beta_{0i}=\beta_0$ and standard slope parameters for each variable in the model. Almost all of the

Table 1. OLS and 2SLS Estimation Results for the Environmental Kuznets Curve (EKC)

Variable	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*
C	1.50565*** (0.25045)	1.57467*** (0.584)	5.19918*** (0.8145)	5.093*** (0.4276)	-139.5621* (79.829)
GDP_{it}	**0.00085***** (7.96e-05)	**0.00085***** (0.00014)	**6.8e-05** (0.00012)	**8.17e-05***** (3.62e-05)	**0.00296***** (0.0012)
GDP^2_{it}	**-9.28e-09***** (2.19e-09)	**-9.28e-09***** (2.38e-09)	**1.72e-10** (1.87e-09)	**-**	**-1.749e-08*** (1.049e-08)
$SCIART_{it}$	**-0.00034***** (4.16e-05)	**-0.00034***** (0.00013)	**-3.08e-05** (3.4e-05)	**-3.14e-05*** (1.87e-05)	**-0.0013** (0.0023)
$KYOT_{it}$	**-2.9948***** (0.43494)	**-3.367**** (1.45074)	**-0.1422** (0.215)	**-0.1486** (0.1663)	**-2.524** (1.942)
LAB_{it}	-4.17e-08*** (3.83e-09)	-4.17e-08*** (1.31e-08)	-9.15e-09 (8.3e-09)	-8.487e-09* (5.07e-09)	6.338e-06* (3.67e-06)
$LAND_{it}$	0.34457 (0.49502)	0.37056 (1.75287)	-0.1288 (1.096)	-0.07682 (0.6305)	0.174 (9.70971)
$ENRG_{it}$	3.54e-05*** (2.98e-06)	3.52e-05*** (1.05e-05)	9.76e-06*** (3.77e-06)	9.812e-06*** (2.11e-06)	-0.00013 (0.0002)
$CONS_{it}$	2.73e-12*** (8.5e-13)	2.68e-12 (2.01e-12)	1.58e-13 (3.18e-13)	1.74e-13 (1.88e-13)	3.0003e-11* (1.78e-11)
CAP_{it}	-1.28e-11*** (1.62e-12)	-1.27e-11*** (5.25e-12)	-3.86e-12*** (1.72e-12)	-3.95e-12 (3.36e-12)	-1.8e-10 (1.36e-10)
Observations	1596	1596	1596	1596	1026
R^2	0,45	0,45	0,98	0,98	-

a) ***,** and * correspond to different statistical significance levels of 1%, 5% and 10%, respectively;
b) R^2 is not reported in the Model 5 due to specific features of the 2SLS estimation method;
c) the standard deviation is reported in the parentheses for each coefficient.
d) all the results for panel data estimation obtained with White correction procedure, for the pooled OLS estimation the White heteroskedastisity consistent coefficient covariances were used

coefficients are statistically significant; however, there are unexpected negative values for β_5 and β_9. Overall, Model 1 supports existence of the Environmental Kuznets Curve. Even though this outcome is significant, it is probably biased because sample covers large period of time, in which years differed from one another; and because sample consist of the countries that alter in terms of size, geographical location, institutional development, initial wealth and etc. Therefore, it is relevant to count for the difference across periods and later for the difference over the countries.

In the subsequent columns, the reported result follow Fixed Effects (FEs) estimation; the analysis will start with consideration of the period specific effects, Model 2, and continue with combination of the period and cross-section fixed effects, Model 3. Since period FE for panel data set approach is applied for the estimation of the Environmental Kuznets Curve relationship, β coefficients now are more consistent. From the table it can be observed that main variables GDP, GDP^2, SCIART and KYOT are statistically significant and meet the expectation on the sign of the relationship with dependent variable CO_2 emission. Comparing to the pooled OLS estimation, achieved effect for the majority of variables started to be larger preserving their statistical significance; however, one of the covariates that stands for the level of consumption in the economy became insignificant and the capital formation variable contradicts the theoretical expectations for the positive sign of the β_9 coefficient. This outcome can be explained by the insufficiency of the econometric method.

In order to obtain more relevant results the same model specification will be estimated taking into account not only time specific effects, but also country specific effects. In other words, the Model 3 will present results for the panel data OLS estimation with period and country fixed effects. The minor side effect of the introduction of cross section FEs is that the number of statistically significant variables decreased. Additionally, even the main explanatory variable, GDP, did lose its explanatory power for the CO_2 emission and the quadratic term started to be insignificant. From this it can be concluded that Model 3 does not capture the inverse U-shape form of the EKC relationship. These facts tell about inappropriateness of the undertaken econometric approach. Another sign of the problem with the choice of the estimation technique is the persistent significance of the misleading term, CAP. They demonstrate reverse relationship with CO_2 to what is expected in theory. In like with Smulders et al. (2010), I argue that existing endogeneity in the main explanatory terms cause unexpected result of the last estimation. Since pollution level corresponds to and determines the economic performance and, in its turn, the latter will influence the state of the environment in the country, we suspect bias caused by endogeneity in the estimation. Additionally, the model specification includes proxy for technological progress and development, the number of scientific and technical articles volume; this variable is also highly endogenous because of its interdependence with GDP level and GHG production. Before, starting the procedure that will correct for the freshly defined problem, I will discuss possibility of nonexistence of the quadratic relationship for the EKC.

The fourth model is different in a sense that I omit from the analysis quadratic term for the GDP. Saying in other words I will assume the linear relationship for the EKC. After this manipulation, from the Table 1it can be observed that results for the slope parameter of the economic performance started to be significant as well as technological advance proxy returned its explanatory power. However, it can be noticed easily that all of the coefficients significantly decreased in the amount of the effect that they had over the level of the CO_2 emission. The same conclusion can be drawn from the previous model. It means that with extension of the econometrical analysis and with its complication and count for cross section and period fixed effects I get estimates that are decreasing in their explanatory power as well as size of the effect they have. In the conclusion remarks over the four models that were estimated previously it is important to mention response of the Kyoto Protocol β coefficient. The situation with this parameter is analogical to what happened to the all βs in the regression. It experienced loss of its statistical significance and reduction of its influence on the dependent variable. The main explanation for this is that as international prevention measure against climate change the Protocol is not effective. It is true to the following reasons. The time period for which it was ratified is small for obtaining the global effect in the GHG emission. Of course, this agreement had not enough time and participants in order to demonstrate it positive effect on the prevention of the pollution level increase. Regarding discussion of the Kyoto Protocol, it is necessary to mention that nonetheless the change in the econometric approach and overall loss of statistical significance the relationship with CO2 emission is always stays to be negative.

After overall description and analysis of the results from the previous models, I will go to the 2SLS procedure that will be used for the estimation of the basic econometric model (equation 1) and that will be used against the endogeneity bias. This method of estimation is very effective in the model where the variables are endogenous and it allows to obtain consistent estimators in this situation. The method works with the help of instrumental variable (IV) that should be provided to each and every endogenous variable in the model. In fact it is hard to find proper instrument in real life; therefore, I will use advantage of the panel data and employ lagged values of the endogenous variables as the IVs. Following the definition of the instrumental variables I form main criteria according to which they will be chosen as well as I will make necessary assumptions. The best instrument is the one that is highly correlated with the independent variable and that is not correlated with error term. In the model, I define GDP_{it}, GDP^2_{it}, $CO2_{it}$ and $SCIART_{it}$ as endogenous variables and based on the simple correlation criteria I am combining IVs list that includes GDP_{it} (-5), GDP^2_{it} (-5), $CO2_{it}$ (-2) and SCIART $_{it}$(-5) lagged variables. It is necessary to assume that Cov (GDP_{it}(-5), u_{it}) = 0, Cov (GDP^2_{it}(-5), u_{it}) = 0, Cov ($CO2_{it}$(-5), u_{it}) = 0 Cov and ($SCIART_{it}$(-5), u_{it}) = 0. Of course, the number of the observation decreased with this econometrical procedure from 1596 to 1026. However, the sample size is still big enough to get credible results.

In the Table 1, the fifth column reports coefficients values, standard errors and indicates statistical significance level for the 2SLS estimation procedure. The method demonstrates that inverse U-shape pattern is statistically significant for the Environmental

Kuznets Curve, both β_1 and β_2 coefficients have explanatory power on the 1 % and 10% significance level respectively. Comparing to the results for the pooled OLS and cross section and period fixed effects for the panel data estimation, those coefficients significantly increased in the size of the effect they have on the dependent variable. The slope parameter for the technological and development progress, SCIART, reached the bigger value; however, it started to be insignificant. Based on this outcome, I conclude that the number of the scientific and technical articles is not the best proxy for the technological progress. In keeping with Smulders et al. (2010) who mention that it would be important to endogenize technology as this will improve the model, but it would be hard to find good enough proxy for these purposes. With respect to the estimation of the Kyoto Protocol effect on the level of the CO_2 emission I am reporting statistical insignificance of the agreement. It means that even taking care of the problems in the regression in cross country differences, time differences and endogeneity bias does not allow to obtain meaningful β_4 coefficient. As the consequence, more powerful and demanding international GHG emission control mechanism should be developed by the global community. Finally, not all of the exogenous variables are significant. The variables like capital formation has no explanatory power in the model, therefore, confusing negative sign should not be used for the further output interpretation. The same logic is true for the energy consumption variable. The positive change that occurred in the result of econometric methodology improvement is the significance of the β_5 slope parameter for the number of people in the labor force. At first, for the pooled OLS estimation, it was misleading with negative influence direction on the pollution level in the country. When the 2SLS was applied, labor force influence obtained bigger absolute value of its influence and as well statistical power. Analogically valuable outcome was achieved for the consumption level variable and β_8 coefficient correspondingly.

Continuing the discussion of the Table 1 results, it is important to pay attention for the R^2 reporting. In the first two models the coefficient of correlation tells about ability of the regression to explain around 45 % of the variation in the explained variable. With evolution of the econometrical approach the value of this parameter increases up to 98%. From the first sight, this statistics seems to be exceptionally good result; however, it can be not because with the use of panel data structure the R^2 always gets higher and in many cases it is not informative. For the 2SLS procedure, R^2 is not reported due to procedure specific features and the calculating for the correlation coefficient those make it completely spurious.

The part for estimation results discussion defined as the task to analyze and compare results from the five different econometric modeling approaches. In order to reach the most consistent and credible result the simple pooled OLS, panel data period fixed effect, panel data period and cross section fixed effect, and two stage least squares (2SLS) were estimated. Except 2SLS, all methods failed to count for the endogeneity problem incorporated into the Environmental Kuznets Curve relationship. After correction for the endogeneity bias, consistent estimators were obtained. The econometric analysis succeeded to provide evidence for the inverse U-shape dependence between economic performance and pollution of the environment. One of the aims of the current research was check for the effect of the Kyoto Protocol on the overall situation with CO_2 emission level. Unfortunately, this agreement does not have enough power to stop constantly growing production of GHGs into the atmosphere. Consequently, more powerful restrictive joint initiative or agreement should be developed on the international level in order to prevent destructive effects of the climate change. Other than that my work was innovative in a sense that I conducted a try to endogenize technological advance in this paper. For that purpose, the number of scientific and technical papers in the country was introduced into the model as the proxy. In the first models the attempt was promising; however, after application of the more advanced methods for the model estimation, the SCIART variable lost its explanatory power. The conclusion on the imperfectness of the proxy variable was done.

In the next section, the whole paper will be summarized. The total contribution of the work into research of the EKC relationship will be discussed. The overall conclusion of the paper will be provided in the subsequent section. The possible direction of the research will be proposed in the end.

6. *Conclusion*

Nowadays, the question of the economic performance and environment quality interaction started to be important. New theory of Environmental Kuznets Curve started to combine the main concepts. It developed from the early attempts to define patterns of the GDP and GHG emissions relationship. From the very beginning it evolved a lot – starting from the microeconomic modeling of demand and supply for clean environment and finishing with the most prominent Schumpeterian endogenous growth theory with pollution. At the same time, many secondary questions to this theory attracted attention of the scientific world. One of those topics, for example, is an evaluation of the Kyoto Protocol performance. The current research paper has as an aim to test empirically Environmental Kuznets Curve taking into account endogeneity issue of the relationship. As well, I had as a task to endogenize technology in the standard EKC model and attempt to conclude about effectiveness of the Kyoto Protocol.

In order to accomplish these goals the 114 country panel data set for the time span of fourteen years was employed. It was not necessary to have any manipulation with the data; additionally, since the data was obtained from the World Bank, the Intergovernmental Panel on Climate Change, and the United Nation Framework Convention on Climate Change, this assures credibility in the results obtained through the testing procedures. The basic model specification was based on the mixture of two papers, Smulders et al. (2010) and Maradan and Vassiliev (2005). The estimation procedure included three models -- pooled data, panel data model with period fixed effects and panel data with period and cross-section fixed effect -- and two basic econometric techniques – Ordinary Least Squares (OLS) and Two Stage Least Squares (2SLS). After careful analysis of the obtained results, it was concluded on the efficiency and properness of 2SLS method.

As the main finding of the paper, I confirmed existence of the inverse U-shape relationship between economic performance and quality of the environment. This result was supported not only by the Two Stage Least Squares procedure but also by the OLS in the models for pooled data, and panel data with period fixed effects. Therefore, we can imply that with achievement of some level of GDP, the level of CO2 emission will be decreasing. In real life, this outcome can be reached through research and development mechanism, for example. Regarding, the attempt to endogenize technological advance into the model results were not that much successful. Through the 2SLS econometric technique insignificance of the progress in the EKC relationship was proved. However, the logical explanation for this outcome is non-availability of the good proxy variable for the technology development. Opportunity to find good data for technology would have provide evidence of the innovation and progress involvement into the formation of the environmental quality and economic performance relationship. The goal to estimate effect of the Kyoto Protocol on the EKC was partially successful. On the one hand, each and every estimation technique and model proved negative impact of the agreement on the pollution level; on the other hand, this result was almost marginally significant. This outcome suggests that the Protocol approaches the goal to preserve or decrease level of the GHG emission; however, it works not in full measure. The only suggestion that is possible in this situation is about development of the better international restrictive measure that will cover not only part of the countries but that would be obligatory for each country of the world.

Overall, I can state that the current research achieved its goals and provided strong evidence for the Environmental Kuznets Curve. Partially successful test of the secondary questions on the relevance of the technology inclusion in the EKC model and effect from the Kyoto Protocol gives valuable suggestions for the further research directions. First, it would be important to obtain better proxy variable for technological progress. Second, following the new trend of the simultaneous system equations estimation in fighting with endogeneity in the variables, it would be contributive to test the EKC using, for example, Three Stage Least Squares (3SLS) econometric technique. In this case, the results for estimates will be not only consistent but more efficient. However, not only results of the current research left out the ways in which development of the EKC theory can be continued. It would be valuable as well to test different theoretical hypothesis connected with the economic performance and environmental quality relationship. For example, theoretical work of Whalley and Yuan (2009) opens opportunities to connect basic EKC theory with financial sector of the economy. Indeed, it would be innovative to evaluate the response of the insurance and financial services innovations to the changes in the climate provoked by the increase of the pollution level. Therefore, I see many perspectives in which the work in the field of Environmental Kuznets Curve can be extended. The vast of the literature on the topic proposes possible direction for the future research.

7. *Works Cited*

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