Original scientific paper
DOI: /10.5513/JCEA01/20.2.2131
Journal of Central European Agriculture, 2019, 20(2), p.712-740

Environmental Kuznets Curve in Croatia: panel data approach with Croatian counties

Kuznetsova krivulja okoliša u Hrvatskoj: pristup analize panel podataka nad hrvatskim županijama

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ABSTRACT

Concept of sustainable development (SD) has been in the focus of researchers and policy makers in the last two decades. SD is closely linked to the preservation of environment. This paper focuses on finding Environmental Kuznets Curve (EKC) relationship between economic development and pollution in Croatia. In order to empirically evaluate existence of this curve, data on 21 counties for different pollutants and income per capita has been obtained for the period 2008-2016. Different specifications of the relationship are observed: linear, quadratic and cubic, with addition of examining whether the Croatia's accession to the EU has made a significant impact on lowering pollution. Moreover, variables in levels and differences have been analyzed in models. Results show that no EKC relationship is found for all pollutants (CO, CO_2, NO_2, SO_2 and PM_{10}) and that entering EU had a positive impact on diminishing pollution in Croatia.

Keywords: air pollution, Croatian counties, Kuznets curve, panel data

SAŽETAK

Koncept održivog razvoja je u fokusu istraživača i nositelja ekonomskih politika posljednja dva desetljeća. Održivi razvoj je povezan s očuvanjem okoliša. Ovo istraživanje se usmjerava na pronalazak Kuznetsove krivulje okoliša (EKC, engl. *Environmental Kuznets Curve*) između ekonomskog razvoja i zagađenja u Hrvatskoj. Kako bi se empirijski procijenila krivulja, podaci o 21 županiji za različite vrste zagađenja su prikupljeni za razdoblje od 2008. do 2016. godine. Različite specifikacije povezanosti se razmatraju: linearna, kvadratna i kubna, uz dodatno razmatranje je li ulazak Hrvatske u Europsku Uniju imao značajan pozitivan učinak na smanjenje zagađenja. Dodatno, u modelima su analizirane varijable u razinama te u prvim diferencijama. Rezultati analize ukazuju da ne postoji EKC povezanost za sve razmatrane oblike zagađenja (CO, CO_2, NO_2, SO_2 i PM_{10}) te da je ulazak Hrvatske u EU imao pozitivan učinak na smanjenje emisija zagađenja u Hrvatskoj.

Ključne riječi: hrvatske županije, Kuznetsova krivulja, panel podaci, zagađenje zraka

INTRODUCTION

With the strongest globalization today and the industry which draws energy resources significantly, there has been an ongoing debate on the concept of sustainable development in the last couple of decades. Sustainable development is defined as rational usage of all resources which does not diminish total wealth of a country for future generations (Pezzey, 1989; Barbier et al., 1990). Since the beginning of 1990s, there has been a rise of research which finds empirical evidence on economic development having a positive effect on environment protection in the long run. A relationship has been discovered between economic development and environment pollution, known under the name Environmental Kuznets Curve, EKC (Kuznets, 1955). Selden and Song (1994) were the first ones to coin the term EKC. The original Kuznets curve observed the relationship between economic development and inequality. The EKC regarding the environment looks cat the relationship between development and pollution in a similar way. As an economy is developing over time, environment pollution is getting bigger. However, after the economy reaches certain level of wealth (income) per capita, the pollution gets smaller. Thus, sustainable development should not present a problem after the economy reaches certain level of income. Of course, pollution reduction is not a spontaneous consequence of the development (see Arrow et al., 1995; Grossman and Krueger, 1996). It is a consequence of conscientious measures of economic policies and a higher awareness level of citizens in the country. As country becomes more industrialized over time, the pollution gets higher because environment is not in primary focus at that point. Moreover, as the country gets more developed, leading sectors of the economy become more "clean", regulation of pollution is introduced and people become more environmentally aware. Over the years, there has been a rise in research which tries to examine the EKC relationship both for developed and developing countries. Based upon the experience of developed countries, trends for developing ones are being forecasted in order to overcome some problems developing countries are facing today. Some of the explanations for the existence of the EKC relationship are the following ones. Costantini and Martini (2006) make distinction between supply side and demand side explanations. Demand side explanations consist of reasoning: when income rises, people are more willing to pay a higher living standard. Thus, from a certain level of income per capita, people are willing to pay more for clean environment compared to the rate of their income growth (clean environment is considered as a luxury good). Supply side is explained in Grossman and Krueger (1995), based upon scale economics and technology effects.

The focus on the relationship between the economic development and pollution has been more profound from the beginning of 1990s. Since economic development affects the pollution level and its changes over time, the EKC curve is being tested more often, by more sophisticated methods and datasets. Moreover, sustainable development should not present a problem in an economy when it reaches a certain level of development, it is important to obtain information on the relationship between those two variables and to implement better economic policies to achieve best results. By analysing previous research, a scarcity of papers which deal with transition countries such as Croatia can be found. Croatia, as other CEE (Central and Eastern European) countries, has gone through dramatic economic, political and social changes in the late 1980s and early 1990s. Those changes could have made consequences on the environment, among other factors. In the last 20 years, liberalization of the market and the whole economy, transformation of the economy and other related issues with opening the once socialistic economy has been prolonged. This also had significant effects on different aspects of the economies, including Croatia. Moreover, Croatia faced many structural and legislation changes due to its accession to the European Union, whose member it became in 2013. Some of the most prominent consequences were the increase of the total wealth and income in the economy, structural changes and relationship towards the environment, especially towards sustainable development. Thus, the purpose of this study is to examine the effects of economic changes in Croatia on environment, by examining existence of the EKC relationship. Previous research which has included Croatia, observed other countries as well (by looking at several CEE countries at once). In that way, panel data was observed and general conclusions were made for a group of countries as a whole. Only two papers until now exist which focuses solely on Croatia, where authors examine only CO_2 emissions on a time series basis. This paper extends the existing research on other pollutants as well and uses data on 21 Croatian counties in order to obtain more insights into the EKC relationship. Consequently, a more detailed discussion on EKC relationship, as well as consequences on economic policy making can be made. Thus, the novelty of this research can be found in analysing the panel data set of Croatian counties for major pollutants (CO_2, CO, PM_{10}, NO_2 and SO_2) for the period 2008-2016 for the first time in the literature so better insights into the EKC relationship could be obtained. There are several reasons on why this research focuses on 5 different pollutants and the county level of analysis. Firstly, there are some regional differences between the level of pollution of different pollutants, due to county being mostly focused on e.g. industry or it being a tourist attraction. In that way, different levels of pollutants can be found by comparing the counties over time. Next, by observing the panel data approach, by combining the spatial and time aspect of the analysis, more data gets available for the analysis (statistical reasoning). Moreover, the panel approach enables obtaining specific county effects due to differences between them on the economic basis, population density, air pollution levels (e.g. countries with refineries compared to those which do not have heavy industry). Since some of the counties heavily rely on manufacturing and pharmaceutics (Koprivnica-Križevci county), some have problems with development after the War of Croatian independence (Vukovar-Srijem county), others heavily rely on tourism as main income generator (e.g. Dubrovnik-Neretva county with more than 60% of total income from tourism; Croatian Chamber of Economy, HGK, 2016). HGK (2016) adds that there are great differences in economic strength between the counties, such as Virovitica-Podravina county and Požega-Slavonija county with the Index of economic strength being on 2/3 of the level of the Croatian average, compared to Grad Zagreb which is 49% above the Croatian average.

The rest of the paper is structured as follows. Second section gives an overview of newer relevant literature which examines the EKC relationship for different countries. Third section describes the methodology used in the study and the fourth section gives results from the empirical analysis. The final, fifth section concludes the paper.

Previous research

Since research on exploring EKC relationship is rapidly growing over the past couple of decades, this section focuses on initial papers which have started the debate, as well as most recent ones which explore countries similar to Croatia. Formal name of EKC curve is derived after S. Kuznets and his famous hypothesis of an inverted U-shape of the curve describing the relationship between income and inequality (Kuznets 1955). Popularization of the relationship between income and pollution has begun with seminal work of Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992) and Panayotou (1993). Grossman and Krueger (1991) was the first empirical study on EKC relationship, where authors observed NAFTA countries. Shafik and Bandyopadhyay (1992) research results had a great impact in literature, due to their results being published in the World Development Report (IBRD 1992). However, lot of research has appeared which looks at the methodological part critically (see, for example, Arrow et al., 1995; Stern et al., 1996).

A summary of relevant research is shown in Tables 1-5, where time span, observed units and pollutants, as well as the main results with some remarks are shown. Table 1 displays the initial relevant research of EKC, which has started the empirical evaluation of the curve. Research in Table 1 mostly focuses on obtaining data from a lot of countries over the world in order to include both developed countries and those which are developing. Papers utilize panel data regression from a methodological standpoint, without testing for causality between observed variables. Thus, majority of the research from this era usually finds the inverted U shape which EKC assumes. Furthermore, these early papers do not test for unit roots in the panel data, due to majority unit root tests being developed almost 20 years after these papers have been published. So, a possibility of some spurious results is present. Table 2 depicts the main results for developed countries in order to get some insights into what happens in the long run when a country's economy becomes stronger. In that way, policy makers in Croatia can observe positive practices. Again, panel data techniques are the most commonly used ones, due to having more data based upon cross section and time series standpoints. The inverted U shape is most common conclusion here as well. For Croatia, this could potentially be important for the empirical results in this research. Namely, if a positive relationship is found between the income and pollution emissions, this could mean that Croatia is still in the upward phase of the inverted U shape curve. Moreover, due to this country being relatively young with small number of data available, if a relationship is found, it could be a positive one as stated, due to this country being in the phase of restructuring and development.

Table 3 extracts only CO_2 pollution, since it is a main contributor to global warming and accounts for 80% of all EU greenhouse gas emissions (European Commission, 2018). Majority of existing research focuses either solely on CO_2 or includes this pollutant in the analysis with other ones. Here, authors focus more on different methodologies, such as observing only time series if possible, authors include Granger causality testing due to implementing assumptions that not only does the income affect the pollution level, but a feedback relationship could be found. This conclusion is what some authors end up with. Thus, it is important to include the fact that changes in pollution levels affect the rest of the economy, either throughout investments or national projects, etc.

Next, Table 4 presents results of various other pollutants and the EKC relationship existence for various countries, since this study observes pollutants as well. Results in this table reveal that when analysis includes different stages of economic growth (country or city level), the inverted U shape of the EKC is found. This means that if the analysis includes different stages of economic development, either by focusing on one country or on a panel dataset, the long-term relationship described in theory could be found. Moreover, when the short and long terms are both included in the analysis, the results sometimes conclude that there is no short-term relationship (in both ways) between the GDP and pollution. Thus, the result in this study could be expected to go in that direction as well.

Analysis of previous studies resulted with couple of conclusions. Majority of authors focus on static panel models, by using fixed effects model. There is less research which uses dynamic models by adding lagged value of the pollutant variable in the model, which has both economic and econometric meaning. Economic interpretation is in Agras and Chapman (1999) and Auffhammer et al. (2001), where authors claim that income does not have instantaneous effects on pollution. It has rather lagged effects. Econometric meaning of including lagged values of the dependent variable as independent one is due to existence of autocorrelation in the model. Moreover, some of the studies do not test for stationarity of variables when using static or dynamic regression models, which could lead to spurious regression problems. Stern (2004) has already warned about this problem in such studies.

Some papers extend the initial model by adding variables which can explain the specific reasons for pollution in some countries. For example, studies of countries in development add variables such as access to drinking water, phone lines supply and other basic measures of development. Countries in transition are observed by adding liberalization effects and other measures which those countries had to implement (see Archibald et al., 2009). Different structures of the economy can contribute to the pollution as well. That is why some research depicts the total economy into different sectors and observes effects of income from different sectors to the pollution. By observing the EKC curve proof in real data, conclusions are often contradictory. Some authors find the typical EKC curve, whilst others find other functional relationship forms between income and pollution: linear, cubic and others (please see Tables 1 to 5). Linear relationship is contradictory to the explanations of sustainable development. Cubic relationship means that two income levels are important. First level is explained as the level in the quadratic relationship (typical EKC curve), while the second level of income is when pollution starts to increase again.

Finally, it can be seen in Table 5 how scarce research on Croatia is. There exist only several recent papers (to author's knowledge) which analyze EKC relationship, but only for carbon dioxide emissions. Previous research regarding Croatia is very scarce. Only several papers were found at this point which concern Croatia. First research was that of Panayotou (1993) where Croatia was included as part of Yugoslavia. Second research was of Mor and Jindal (2012), where Croatia was included in the panel data set. Authors observed CO_2 pollution only, for the period from 1997 to 2008 and the results showed that there is a U shaped relationship between pollution and income, including Croatia. This meant that no EKC relationship was confirmed in the observed period. Jošić, Jošić and Janečić (2016) is one of the two detailed research which observed only Croatia. Authors observe only CO_2 emissions by employing linear regression for the period 1990-2013. They found very weak linear relationship in short-term between the observed variables. When authors included population density and openness of the economy, the variables were not statistically significant. Since no EKC relationship was found, authors explained it with overextended process of consumption of all sectors in the economy and not industrial production. Other research which focused on Croatia was Ahmad et al. (2017). Authors focused on quarterly based data on CO_2 emissions, and observed both the short and long term in the analysis. Only GDP and emissions were included as variables of interested, with bidirectional relationship found in the short run and GDP to pollution in the long run. Thus, the results could indicate some spurious conclusions due to not including other relevant factors in the model (i.e. control variables).

Thus, this study is going to observe other pollutants as well because there is no study existing on effects of development on them. Moreover, by observing Croatian counties by employing panel data, more data is available in order to empirically evaluate EKC relationship in Croatia.

MATERIALS AND METHODS

Since the empirical part of the research deals with panel data (cross sectional with time series combined), this research opted to utilize panel regression. Panel data methodology is widely known in literature, thus this section gives a brief overview of basics by following Greene (2003) and Wooldridge (2002). A basic static panel model is the pooled model denoted as:

$$y_{it} = \alpha + \sum_{k=1}^{K} \beta_k x_{itk} + \varepsilon_{it}, \quad i \in \{1,2,...,N\}, t \in \{1,2,...,T\}, \quad (1)$$

where N denotes number of observed units, T number of time periods, y_{it} value of dependent variable of i-th observed unit in period t, α is the constant equal for each observed unit and it does not change in time, x_{ijk} is the value of k-th independent variable of i-th observed unit in time t, β_k is the value of k-th parameter and ε_{it} is error term of i-th observed unit in time t. Assumptions of the pooled models are:

$$\varepsilon_{it} \sim i.i.d.(0, \sigma_\varepsilon^2) \text{ and } \operatorname{cov}(x_{itk}, \varepsilon_{it}) = 0, \forall i,t,k \quad (2)$$

i.e. all error terms are independently and identically distributed across all observed units and time periods, with expected value 0 and constant variance, with all variables x_{itk} non-dependent on error terms.

Since pooled model is used when all of the observed units are randomly selected in every time period t, it is useful to use for random samples. Thus, more commonly, models with fixed or random effects are used. The double fixed effects model is the following one:

$$y_{it} = \alpha_i + \lambda_t + \sum_{k=1}^{K} \beta_k x_{itk} + \varepsilon_{it}, \quad i \in \{1,2,...,N\}, t \in \{1,2,...,T\}, \quad (3)$$

in which the constant changes for each observed unit (α_i) and time period (λ_t). Model (3) could include only unit effects or time effects, depending upon the assumptions

DOI: /10.5513/JCEA01/20.2.2131

Table 1. Results from initial research on environmental Kuznets curve

Authors	Observed units	Period	Emissions	Econometric methodology	Variables used in the study	EKC hypothesis	Causality
Grossman and Kruger (1991)	52 cities over the world	1977, 1982, 1988	SO_2, dark matter and SPM	Panel regression	Location dummies, population density, trend variable. Emission variables in levels. Income variable adjusted for PPP.	Inverted U shape (EKC confirmed).	GDP to pollution
Shafik and Bandyopadhyay (1992)	47 cities over the world	1972-1988	10 pollutants	Panel regression	Location dummies, trend variable. Income variable adjusted for PPP.	Only two air pollutants have inverted U shape (EKC confirmed), for others no relationship was found or negative linear relationship.	GDP to pollution
Panayotou (1993)	55 developed and developing countries	1987-1988	SO_2, SPM, NO_2	Panel regression	Rate of deforestation, population density. Variables expressed per capita. Croatia included in Yugoslavia.	Inverted U shape (EKC confirmed).	GDP to pollution
Selden and Song (1994)	22 OECD countries and 8 developing countries	1979-1987	CO, NO_x, SO_2, SPM	Panel regression	GDP and pollutants	Linear positive relationship for CO; inverted U shape for NO and SO2 (EKC confirmed).	GDP to pollution

CO_2 - carbon dioxide, CO - carbon monoxide, SO_2 - sulphur dioxide, (S)PM_{10} - (suspended) particulate matter micrograms, NO_x - nitrogen oxide emission.

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Table 2. Results from research on environmental Kuznets curve, developed countries

Authors	Observed units	Period	Emissions	Econometric methodology	Variables used in the study	EKC hypothesis	Causality
Cole et al. (1997)	11 OECD countries	1970-1992	CO_2, NO, SO_2, water pollution	Panel regression	Country dummies, technology level	Inverted U shape (EKC confirmed) for all pollutants except water	GDP to pollution
List and Gallet (1999)	USA states	1929-1994	SO_2, NO	Panel regression	Population density, high school graduates, median age Variables expressed per capita.	Inverted U shape (EKC confirmed)	GDP to pollution
Roca et al. (2001)	Spain	1973 (1980) -1996	CO_2, CH_4, N_2O, SO_2, NO_x, NMVOC	OLS time series	Variables expressed per capita. Nuclear energy and coal consumption added	Inverted U shape (EKC confirmed) only for SO_2, positive linear relationship for others.	GDP to pollution
Xuemei (2005)	24 OECD countries	1975-1990	CO_2	Simultaneous equation system	Population, technology proxy, capital added	Inverse EKC, contrary to many previous results (due to methodology).	Bidirectional
Dijkgraaf and Vollebergh (2005)	24 OECD countries	1960-1997	CO_2	Panel regression	Population, energy consumption. Variables expressed per capita	EKC exists when only using panel data	GDP to pollution

CO_2 - carbon dioxide, SO_2 - sulphur dioxide, NO_x - nitrogen oxide emission, CH_4 - methane, N_2O - nitrous oxide, NMVOC - non-methanic volatile organic compounds.

Table 3. Results from research on environmental Kuznets curve, CO_2 pollutant

Authors	Observed units	Period	Emissions	Econometric methodology	Variables used in the study	EKC hypothesis	Causality
Dinda and Coondoo (2006)	88 countries, developing and developed ones	1960 - 1990	CO_2	Error correction model Granger causality tests	CO_2 emissions and GDP per capita	Quadratic and cubic forms of EKC found.	Bidirectional relationship
Galeotti and Lanza (2005)	108 countries Subsamples of OCED and non-OECD countries observed.	1971-1995	CO_2	Panel regression Gamma and Weibull distributions for better approximations.	CO_2 emissions and GDP per capita	Inverted U shape (EKC confirmed).	GDP to pollution
Coondoo and Dinda (2002)	100 countries	1950-1992	CO_2	Granger's causality test.	CO_2 emissions and GDP per capita	Linear relationship	Developed countries: emissions cause GDP, Developing countries: bi-directional causation.
Niu et al. (2011)	7 Asian countries and Australia	1960-2003	CO_2	Panel regression	Different energy consumption sectors used in order to find which one contributes to EKC relationship. GDP per capita and CO_2 emissions.	Long-term relationship exists, but opposite results for developed and developing countries.	Causality from energy consumption to pollution.
Iwata et al. (2011)	31 countries	1960-2003	CO_2	Panel regression (pooled mean group)	Nuclear energy consumption added into analysis	Linear positive relationship	GDP to pollution

CO_2 - carbon dioxide.

Table 4. Results from research on environmental Kuznets curve, recent research

Authors	Observed units	Period	Emissions	Econometric methodology	Variables used in the study	EKC hypothesis	Causality
Song et al. (2008)	29 Chinese provinces	1985-2005	Waste gas	Panel cointegration	Waste gas, waste water solid waste pollution and GDP per capita	There exists long-run cointegrating relationship; inverse U shape for all pollutants (EKC confirmed)	GDP to pollution
Piłatowska and Włodarczyk (2017)	10 CEE countries	1995-2012	CO_2	Threshold ECM model, momentum ECM model	Energy consumption and trend added in analysis	Inverted U shape for some countries	No short–term causal relationships for Estonia, Romania and Slovenia. GDP to pollution in long run for Romania and Estonia. Bidirectional long run causality for Estonia and Slovenia
Akbostanci et al. (2009)	Turkey and 58 Turksih provinces	1968-2003 (provinces data 1992-2001)	CO_2, SO_2 and PM10	Regression and panel regression	Examination both of time series and panel data. Variables expressed per capita.	Cubic relationship for SO_2 and PM10, no EKC for CO_2	GDP to pollution
Liddle (2015)	84 cities over world	1995	CO, NO_x, VHC	Cross section regression	GDP per capita, pollutants; urban density and fuel prices included as well	Inverted U shape (EKC confirmed)	GDP to pollution

CO_2 - carbon dioxide, CO - carbon monoxide, SO_2 - sulphur dioxide, NO_x - nitrogen oxide emission, VHC - volatile hydrocarbons, SO_x - sulphur oxide, ECM - Error correction model.

Table 5. Results from research on environmental Kuznets curve, Croatia included

Authors	Observed units	Period	Emissions	Econometric methodology	Variables used in the study	EKC hypothesis	Causality
Mor and Jindal (2012)	39 countries, Croatia included	1997-2008	CO_2	Panel data regression	Variables expressed per capita	U shape and opposite N shape for majority countries, Croatia as well	GDP to pollution
Kasman and Duman (2015)	New EU members and candidate countries	1992-2010	CO_2	Panel data regression	GDP, pollution, openness of a country, urbanization	Inverted U-shape	Unidirectional casualty from energy, openness and urbanization to emissions in short and long term.
Jošić et al. (2016)	Croatia, aggregate data	1990-2013	CO_2	Johansen cointegration test	Trade openness, population density. Variables expressed per capita.	Positive linear relationship in short term. No cointegration was found.	GDP to pollution, only short term.
Ahmad et al. (2017)	Croatia, aggregate data	1992Q1-2011Q1	CO_2	ARDL VECM DOLS	GDP	Inverted U-shape	Bidirectional in short run; GDP to CO2 in long run
Allard et al. (2017)	74 countries, Croatia included	1994-2012	CO_2	Quantile panel regression	GDP, renewable energy consumption, technological development, trade, and institutional quality	N shaped curve	GDP to pollution

CO_2 - carbon dioxide, ARDL - Autoregressive Distributed Lag, VECM - Vector error correction model, DOLS – dynamic ordinary least squares of the researcher or the statistical characteristics of the model.

(Double) random effects model assumes the following:

$$y_{it} = \alpha + \sum_{k=1}^{K} \beta_k x_{itk} + \lambda_t + e_i + \varepsilon_{it}, \quad i \in \{1,2,...,N\}, t \in \{1,2,...,T\}, \quad (4)$$

where observed units are collected randomly and each random effects could change for each unit (e_i) or time (λ_t). Again, one can assume only unit or time random effects. Assumptions of the model are the following ones:

$$\begin{gathered} e_i \sim i.i.d.(0,\sigma_e^2),\ \varepsilon_{it} \sim i.i.d.(0,\sigma_\varepsilon^2), \\ \mathrm{cov}(e_i, x_{itk}) = 0, k \in \{1,2,\dots,K\}, t \in \{1,2,\dots,T\}, \\ \mathrm{cov}(e_i, \varepsilon_{it}) = 0, t \in \{1,2,\dots,T\}. \end{gathered} \quad (5)$$

In order to choose an adequate model, *F*-test is used to compare fixed effects model to the pooled regression, by assuming that in model (3) the values of unit constants are as follows:

$$\begin{aligned} &H_0 : \alpha_1 = \alpha_2 = \dots = \alpha_N = \alpha \\ &H_1 : \exists \alpha_i \neq \alpha, i \in \{1,2,\dots,N\} \end{aligned}, \quad (6)$$

or assuming the time constants in hypotheses:

$$\begin{aligned} &H_0 : \lambda_1 = \lambda_2 = \dots = \lambda_T = \lambda \\ &H_1 : \exists \lambda_t \neq \lambda, t \in \{1,2,\dots,T\} \end{aligned}, \quad (7)$$

or a test combining both unit and time in-variation. Hausman test is used in order to compare estimations of fixed and random effects models:

$$\begin{aligned} &H_0 : \mathrm{cov}(e_i, x_{itk}) = 0\ \forall k \\ &H_1 : \exists x_{itk} : \mathrm{cov}(e_i, x_{itk}) \neq 0, k \in \{1,2,\dots,K\} \end{aligned}, \quad (8)$$

where it is tested if correlation between individual effects and independent variables exist. If this correlation exists, the fixed effect estimator is the only one consistent. If the correlation is not significant, than both estimators are consistent and both fixed and random effects model can be used. Finally, a Granger test can be conducted to test for causality between the variables in a model. Namely, previous literature often tests if there exists causality from the pollution variables to the GDP variable. Thus, this research opted to provide a simple test in which the following regression is estimated:

$$y_{i,t} = \alpha_i + \sum_{k=1}^{K} \gamma_{ik} y_{i,t-k} + \sum_{k=1}^{K} \beta_{ik} x_{i,t-k} + \varepsilon_{i,t}, \quad (9)$$

where the test can be conducted as the original Granger test for time series data, where H_0: $\beta_{i1} = \dots = \beta_{ik} = 0\ \forall i$ (no causality for all countries in the panel). The other test is Dumitrescu-Hurlin (2012) test where causality can be for some countries and for some not (the alternative hypothesis distinguishes betas between some countries having zero values and some not). Since this research deals with a small number of time series data aspect in the panel, the lag length (*K*) will be chosen to be 1 and 2. More details on panel data models can be seen in Maddala (2001), Verbeek (2002), Wooldridge (2002), Arellano (2003), Greene (2003) or Brooks (2008). The results of the empirical analysis for Croatia are given in the next section.

RESULTS AND DISCUSSION

For the purpose of empirically evaluating EKC relationship in Croatia, yearly data on Gross Domestic Product (GDP), population and surface area for 21 counties was collected from the Croatian Bureau of Statistics (2018). Pressure variable was calculated for each county in each year as the ratio of surface area and population. Data on pollution in each county was collected from the Croatian Agency for the Environment and Nature (2018) for the following available pollutants: carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), particulate matter (PM_{10}) and sulphur dioxide (SO_2). All of the pollutants are measured as total kg emissions per year. Data is available only on a yearly basis for the period from 2008 until 2016. In that way, for each variable 9 yearly observations are obtained. Every variable was transformed by dividing it with population number, as previous literature uses per capita variables. Pollutant and GDP variables are the basic ones in the EKC relationship. Other variables could be added in the analysis as control variables. In this study pressure is added as a control variable due to its availability for every county. The pressure variable is justified based upon Malthusian theory of population, in which environmental degradation is amplified due to greater pressure (see Grossman and Kruger, 1991; Akbostanci et al., 2009; Jošić et al., 2016); and some of the counties in Croatia face great pressure over the summer months due to great inflow of tourists. This leads to risks of environment degradation and lowering the attractiveness of a destination (for more details see Alkier Radnić, 2003). Moreover, Kružić (2004) lists some of the problems in Croatian tourist destinations regarding the pressure on environment, such as irresponsible disposal of waste, bad planning of municipal waste infrastructure, etc.

All of the variables were logarithmed in order to reduce the variance of data. Original series are shown in Tables 6, 7, 8 and 9 where descriptive statistics is calculated for the overall average and for every county as well, with full names of counties. On average, the pollution has been slowly decreasing over the examined period for all pollutants. Graphical representations of values of pollutants over the years are shown on Figures 1-6, where this is more visible. The greatest air pollutant in Croatia is, as expected, CO_2. Emissions of SO_2 and NO_2 are below the ceilings put in Gothenburg Protocol and NEC Directive, ever since 2015. SO_2 emissions decreased due to sulphur recovery plants installed within the refineries (last one in 2008). Croatian Agency for Environment and Nature (2017) states that NO_2 and PM_{10} emissions have declined over the years after the crisis in 2007/2008 and this was

Table 6. Mean values of every variable in the analysis

	PM_{10}	NO_2	SO_2	CO_2	CO	Population	GDP
Total average	123650	12366296	1498433	465747751	1455451	204770	15952740
BJEL-BIL	331986	19319053	80215	136003593	19978936	118841	6502721
BRO-POS	209374	33092	54333	31445193	60335	160292	7104572
DUB-NER	706	981880	282671	11443302	2169	123952	9284146
ZAGREB	79636	1689533	2455480	1298980888	269868	794510	109549947
ISTAR	291620	226873924	4509560	2422750345	1867069	210238	20454571
KARLO	55961	74728	308296	57752851	43901	127062	7559094
KOP-KRI	13067	147512	71135	524044414	157014	115592	8104255
KRA-ZAG	108295	442883	276016	143374850	35706	132324	6585868
LIC-SENJ	20137	43205	32693	74734940	438737	49195	3208717
MEDJ	25325	12246	2151901	23711733	11266	114695	7293909
OSJ-BAR	213044	1753816	1853115	877493927	2204081	305424	19120476
POZ-SLA	19900	62873	17025	26017576	148454	77342	3745602
PRIM-GOR	158248	2070839	6090119	1093402784	326557	297047	28230606
SIS-MOS	567841	3353751	3421256	1428976496	1732110	167256	10302603
SPL-DALM	84036	1815570	406027	1035676801	2061155	463441	27937151
SIB-KNIN	28566	73624	124386	75728467	117076	108601	6448061
VARAZ	81169	281175	8829183	154167543	291226	175798	11366855
VIR-PODR	79750	72514	9346	65700814	448679	83971	4094982
VUK-SRI	87284	182994	71641	118576619	193580	181375	8426091
ZADAR	97255	73525	150041	26582055	13015	172285	10789211
ZGB	43446	333477	272653	154137574	163533	320937	18898111

BJE-BIL denotes Bjelovar-Bilogora county, PRO-POS Brod-Posavina county, DUB-NER Dubrovnik-Neretva county, GZAGREB Zagreb City, ISTAR Istria county, KARLO Karlovac county, KOP-KRI Koprivnica-Križevci county, KRA-ZAG Krapina-Zagorje county, LIC-SENJ Lika-Senj county, MEDJ Medimurje county, OSJ-BAR Osijek-Baranja county, POZ-SLA Pozega-Slavonia county, PRIM-GOR Kvarner county, SIS-MOS Sisak-Moslavina county, SPL-DALM Split-Dalmatia county, SIB-DALM Split-Dalmatia county, SIB-KNIN Sibenik-Knin county, VARAZ – Varazdin county, VIR-PODR Virovitica-Podravina county, VUK-SRI Vukovar-Srijem county, ZADAR – Zadar county and ZGB Zagreb County.

still ongoing in 2015. The agency also states that the main reason why CO emissions have declined due to increase of vehicles with catalytic converters after the war in early 1990s. Greater values of PM_{10} and NO emissions can be found for Sisak-Moslavina county, followed by Bjelovar-Bilogora and Brod-Posavina county. This is mainly due to industry sources (Ina refinery and thermal power plant in Sisak-Moslavina county), home fireplaces and road traffic in Bjelovar-Bilogora county (mainly PM_{10} and NO emissions, Physical planning department of Bjelovar-Bilogora county, 2015). NO_2 emissions were high in Istria county, due to it being urban and industrial environment (Physical planning department of Istria county, 2017).

Finally, to include comments on the descriptive statistics before the estimation, scatter plots have been observed between GDP per capita and all pollutants per capita on Figures 7-11. Moreover, the differenced variables on their respective scatter plots have been observed on Figures 12-16. Initial insights into Figures show that somewhat relationship could be found in data in levels. However, in differences, there seems to be no relationship between the income and pollution in the observed period.

Table 7. Standard deviations of every variable in the analysis

	PM_{10}	NO_2	SO_2	CO_2	CO	Population	GDP
Total average	229561	146521460	6120488	659176538	12795637	163588	22191106
BJEL-BIL	696067	57346744	146979	50079468	58488932	4912	416364
BRO-POS	343528	10795	43100	5205577	46050	9736	361383
DUB-NER	1071	2917953	679581	2424097	601	2545	236952
GZAGREB	54038	582355	1998993	379092461	133514	4787	1735321
ISTAR	202413	668182803	741034	523650013	964730	3362	547974
KARLO	103242	23404	271168	8742273	34341	4520	415145
KOP-KRI	19930	27433	18999	154072675	111303	3269	551522
KRA-ZAG	118399	109883	139669	28402847	28615	3350	505611
LIC-SENJ	23310	28124	16023	99136689	438141	1291	300658
MEDJ	16146	4365	6407283	9422041	6451	2457	199512
OSJ-BAR	62575	812775	627330	69089699	524019	11206	832553
POZ-SLA	9633	49714	32029	4794664	196422	3780	299386
PRIM-GOR	71940	674190	5627118	305775852	114804	5689	782532
SIS-MOS	192607	947676	2081471	223691493	2482657	5716	506422
SPL-DALM	50414	702039	352924	250922618	648587	14194	991727
SIB-KNIN	25271	25887	100522	10507007	147102	4270	226243
VARAZ	48632	220239	25858777	30924377	231031	3742	530126
VIR-PODR	149367	19149	5449	24557304	1028747	3117	385310
VUK-SRI	32751	165993	23993	60497970	140427	12514	506952
ZADAR	264471	82500	116115	5989646	13305	2553	413118
ZGB	27837	208356	159085	19007765	49857	5541	476934

BJE-BIL denotes Bjelovar-Bilogora county, PRO-POS Brod-Posavina county, DUB-NER Dubrovnik-Neretva county, GZAGREB Zagreb City, ISTAR Istria county, KARLO Karlovac county, KOP-KRI Koprivnica-Križevci county, KRA-ZAG Krapina-Zagorje county, LIC-SENJ Lika-Senj county, MEDJ Medimurje county, OSJ-BAR Osijek-Baranja county, POZ-SLA Pozega-Slavonia county, PRIM-GOR Kvarner county, SIS-MOS Sisak-Moslavina county, SPL-DALM Split-Dalmatia county, SIB-DALM Split-Dalmatia county, SIB-KNIN Sibenik-Knin county, VARAZ – Varazdin county, VIR-PODR Virovitica-Podravina county, VUK-SRI Vukovar-Srijem county, ZADAR – Zadar county and ZGB Zagreb County.

Table 8. Minimum values of every variable in the analysis

	PM_{10}	NO_2	SO_2	CO_2	CO	Population	GDP
Total average	21	3133	347	7044081	1302	46888	2898250
BJEL-BIL	32774	90961	3497	79358443	176732	111867	6050257
BRO-POS	265	14811	4099	23329476	8055	148373	6647578
DUB-NER	21	3133	15379	7044081	1302	121970	8984927
GZAGREB	22477	886977	258029	816255243	77074	788095	105965457
ISTAR	131164	2502263	3665034	1187985164	556320	207719	19796781
KARLO	4793	46735	24586	39833505	10031	120321	7136575
KOP-KRI	2419	112592	32774	266890390	35185	110976	7419887
KRA-ZAG	26100	257726	165405	112783456	7018	127748	6002298
LIC-SENJ	3858	19257	16196	22706547	72745	46888	2898250
MEDJ	2334	6011	2066	11461476	3757	112089	6929738
OSJ-BAR	150567	1010668	1253502	756569834	1843205	290412	18303414
POZ-SLA	7894	27789	347	19667440	16213	71920	3332090
PRIM-GOR	95763	1249557	1683041	855948236	178884	289479	27075161
SIS-MOS	302136	2095334	1384281	1137286498	321903	157204	9256966
SPL-DALM	29142	941049	58901	601455860	1239321	452035	26930960
SIB-KNIN	11445	39226	5047	57079126	12605	103021	5990728
VARAZ	30885	115003	77960	107822661	93841	170563	10714145
VIR-PODR	16548	50022	1437	25972460	71065	79111	3540223
VUK-SRI	38839	60621	39722	52860481	67849	165799	7783581
ZADAR	4098	28849	22497	16999835	2324	169581	10459335
ZGB	22363	130447	116730	124758060	92193	314549	17912055

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Table 9. Maximum values of every variable in the analysis

	PM_{10}	NO_2	SO_2	CO_2	CO	Population	GDP
Total average	2179081	2008693818	77785387	2844986688	175947214	802338	111165176
BJEL-BIL	2179081	172243467	426363	236885167	175947214	125652	7027915
BRO-POS	875174	45347	99002	38567968	135816	173628	7675255
DUB-NER	3526	8763082	2075183	14717187	3258	127746	9749291
GZAGREB	170937	2635170	5976693	1739774338	470420	802338	111165176
ISTAR	810350	2008693818	5535291	2844986688	3136771	214991	21597655
KARLO	326595	111552	823811	70170262	105811	133405	8238099
KOP-KRI	65225	197934	91220	718402621	393758	120106	9065541
KRA-ZAG	413492	583615	519027	186036489	84238	137001	7404671
LIC-SENJ	77762	100042	52262	335769791	1457132	50697	3623700
MEDJ	50193	18708	19237958	35855112	20301	117923	7539679
OSJ-BAR	331633	3092019	3149391	960750773	3554254	320617	20697689
POZ-SLA	42055	182651	87152	36277300	659049	82548	4214728
PRIM-GOR	333240	3195694	19890969	1877106998	463202	304750	29117950
SIS-MOS	821079	4650478	7910594	1886381912	8198338	174301	11035161
SPL-DALM	178955	3148007	996666	1454844871	2818817	482604	29770842
SIB-KNIN	88176	124599	309546	93430993	443690	114283	6779187
VARAZ	201810	721614	77785387	194626942	820932	180781	12224766
VIR-PODR	472977	100648	15768	104223361	3190810	88299	4655478
VUK-SRI	132712	564420	109529	262728870	432814	198289	9243619
ZADAR	802439	288515	316848	36116030	39201	176316	11785750
ZGB	110584	750031	492519	178208889	229610	329253	19458139

BJE-BIL denotes Bjelovar-Bilogora county, PRO-POS Brod-Posavina county, DUB-NER Dubrovnik-Neretva county, GZAGREB Zagreb City, ISTAR Istria county, KARLO Karlovac county, KOP-KRI Koprivnica-Križevci county, KRA-ZAG Krapina-Zagorje county, LIC-SENJ Lika-Senj county, MEDJ Medimurje county, OSJ-BAR Osijek-Baranja county, POZ-SLA Pozega-Slavonia county, PRIM-GOR Kvarner county, SIS-MOS Sisak-Moslavina county, SPL-DALM Split-Dalmatia county, SIB-DALM Split-Dalmatia county, SIB-KNIN Sibenik-Knin county, VARAZ – Varazdin county, VIR-PODR Virovitica-Podravina county, VUK-SRI Vukovar-Srijem county, ZADAR – Zadar county and ZGB Zagreb County.

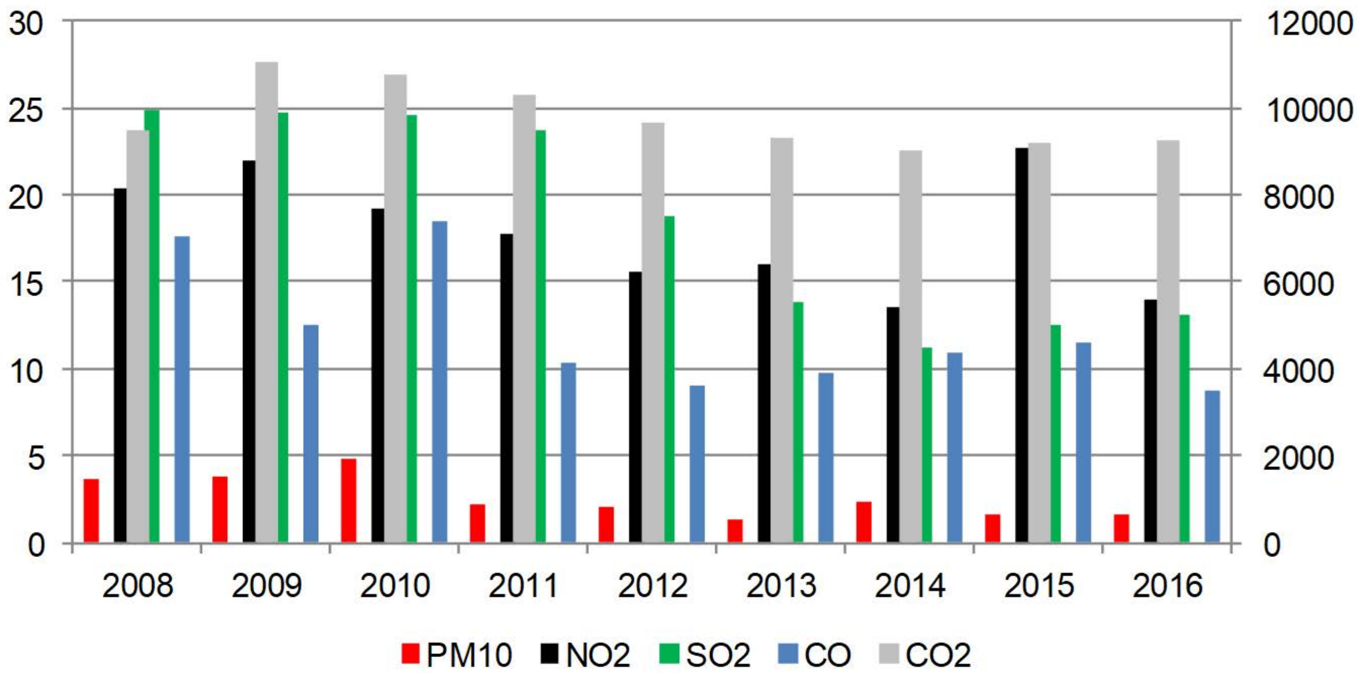

Figure 1. Average emissions of PM_{10}, NO_2, SO_2, CO and CO_2 in Croatia, in tonnes (Left axis refers to PM_{10}, NO_2, SO_2 and CO, right axis refers to CO_2. Source: author's calculation.)

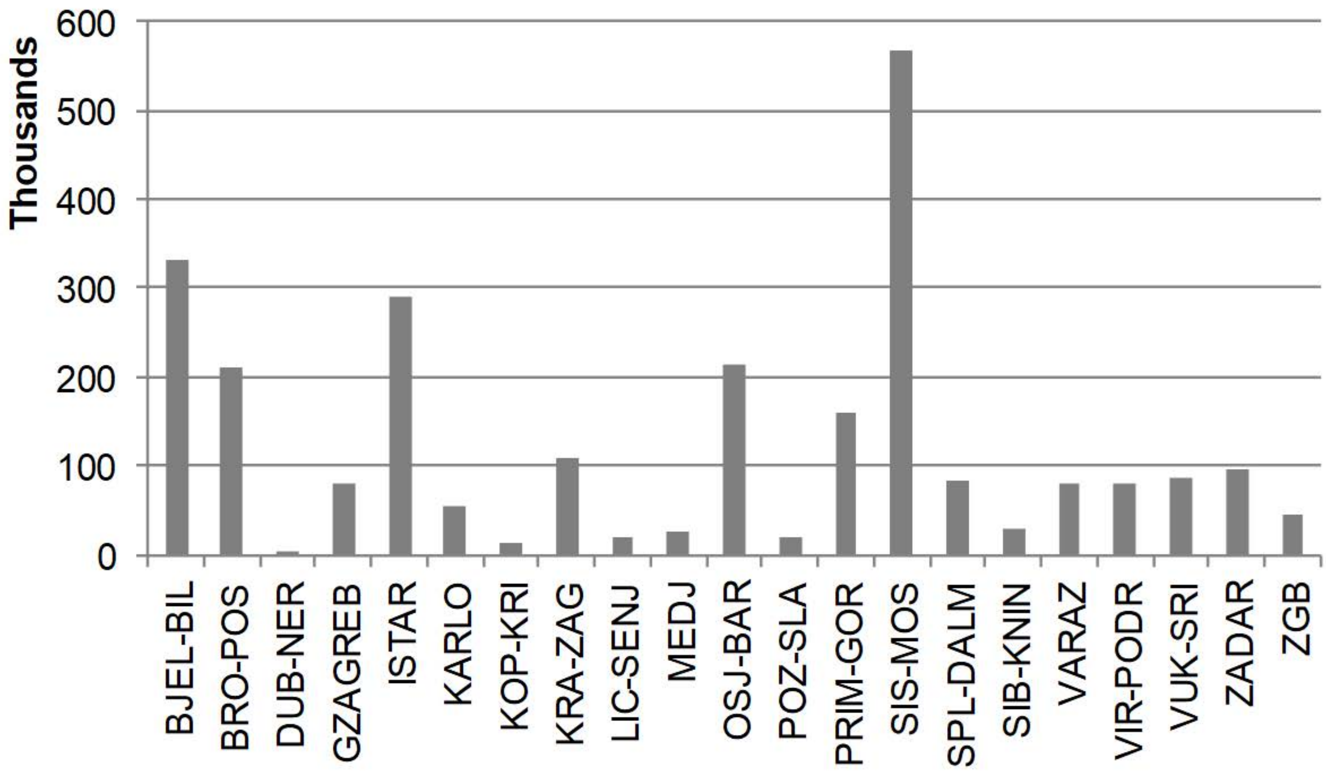

Figure 2. Average emissions of PM_{10} in thousands of kg in every county, period 2008-2016 (Source: author's calculation.)

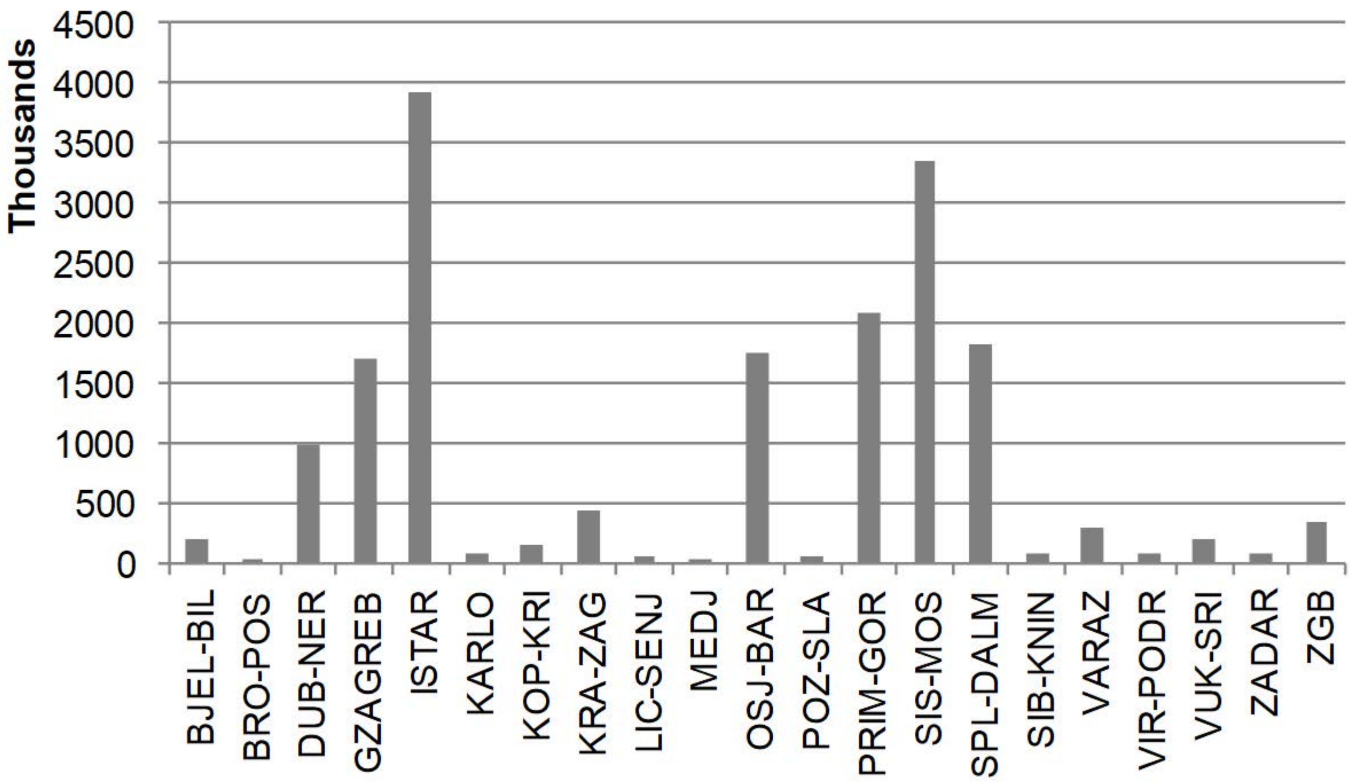

Figure 3. Average emissions of NO_2 in thousands of kg in every county, period 2008-2016 (Source: author's calculation.)

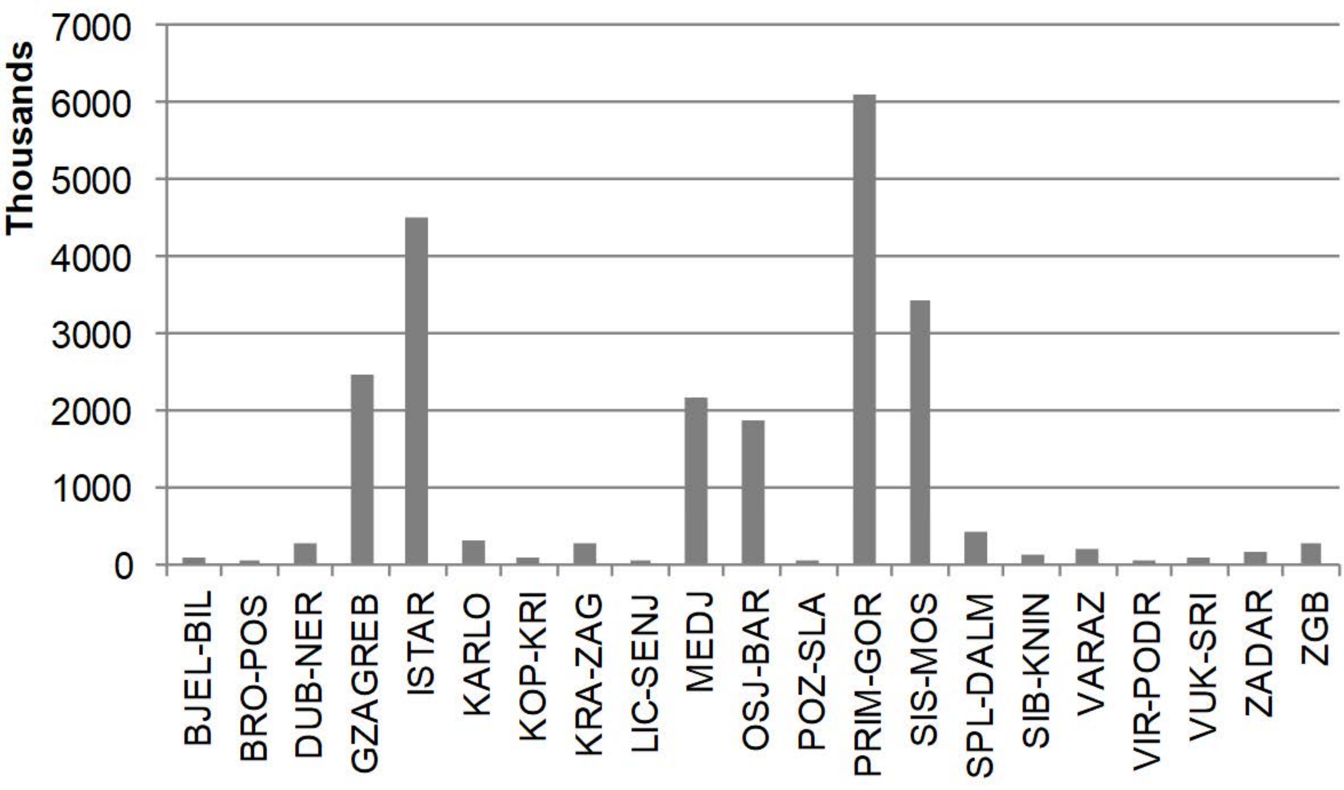

Figure 4. Average emissions of SO_2 in thousands of kg in every county, period 2008-2016 (Source: author's calculation.)

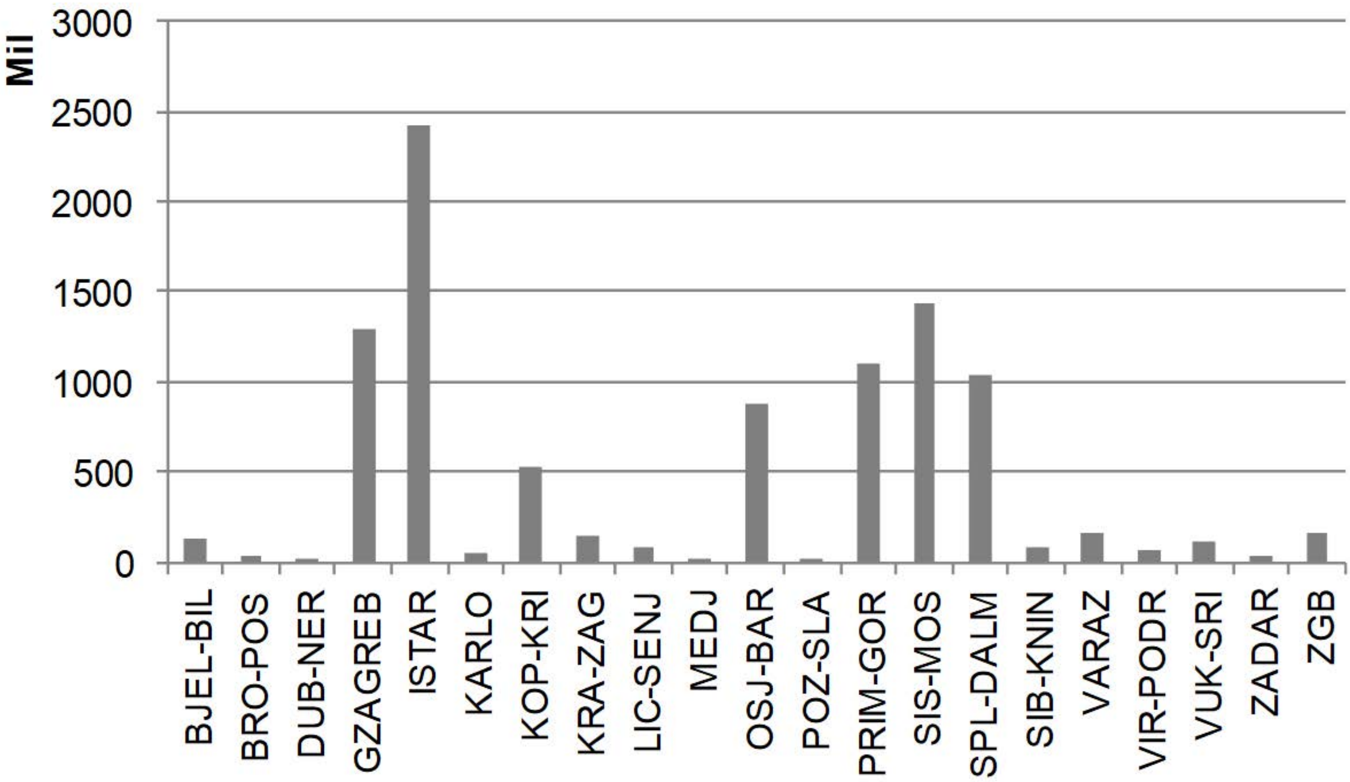

Figure 5. Average emissions of CO_2 in thousands of kg in every county, period 2008-2016 (Source: author's calculation.)

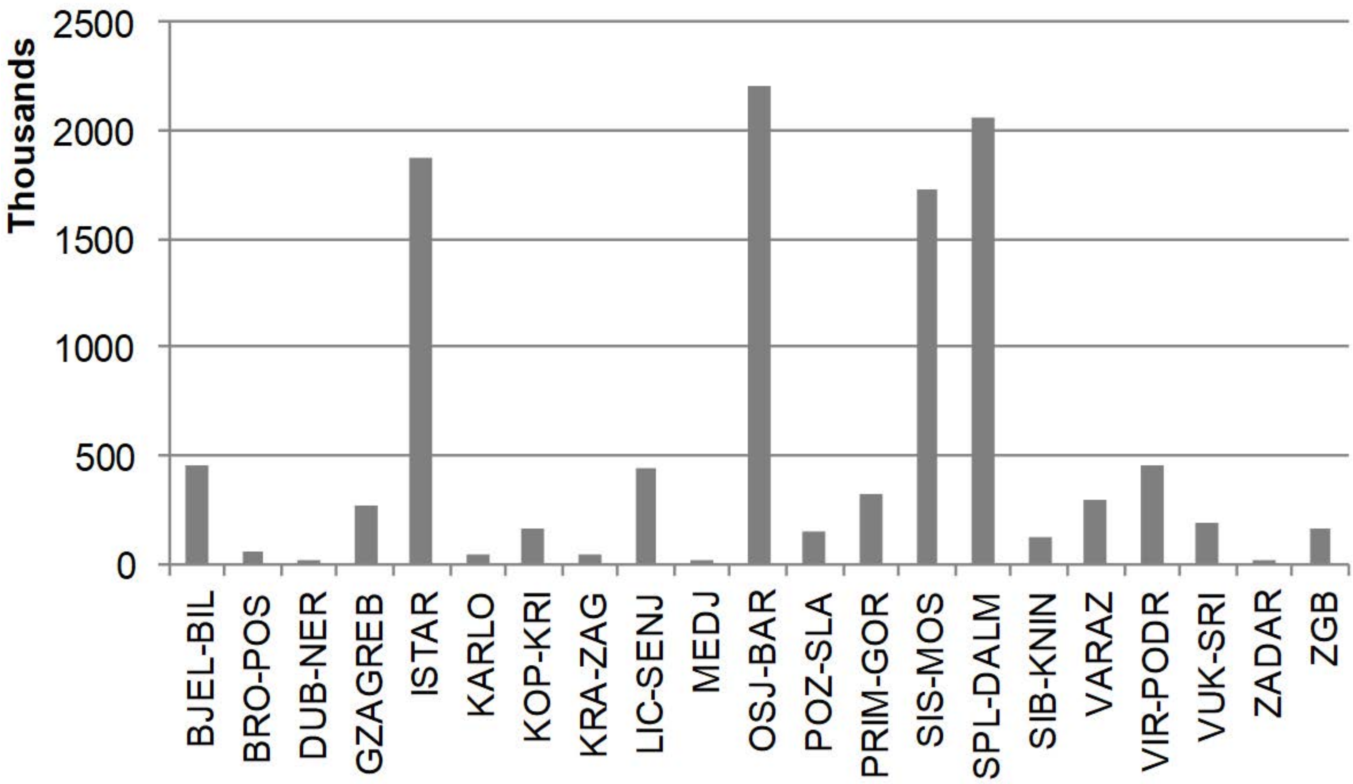

Figure 6. Average emissions of CO in thousands of kg in every county, period 2008-2016 (Source: author's calculation.)

DOI: /10.5513/JCEA01/20.2.2131

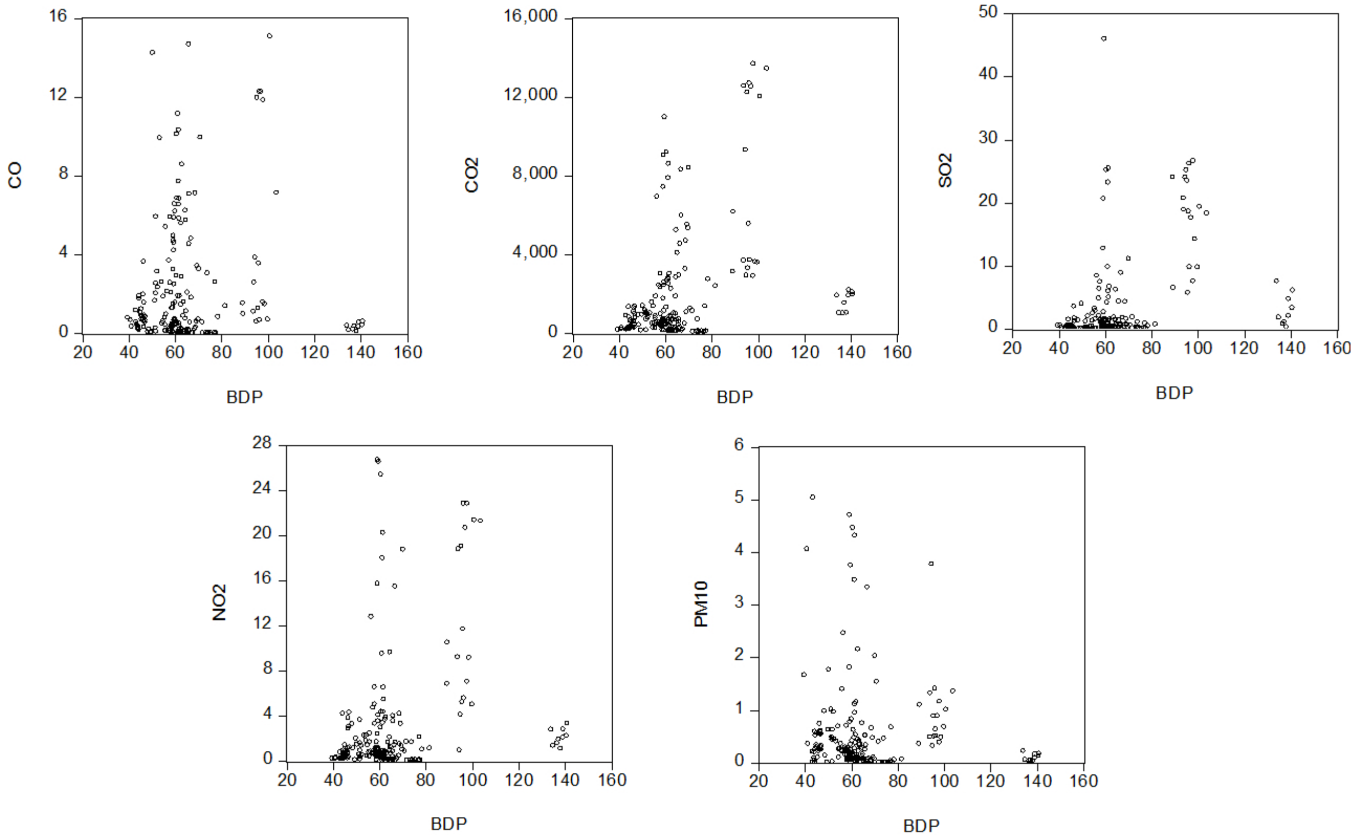

Figure 7-11. Scatter plots for pollutants in levels, in kg per capita versus GDP per capita, panel data (Source: author's calculation.)

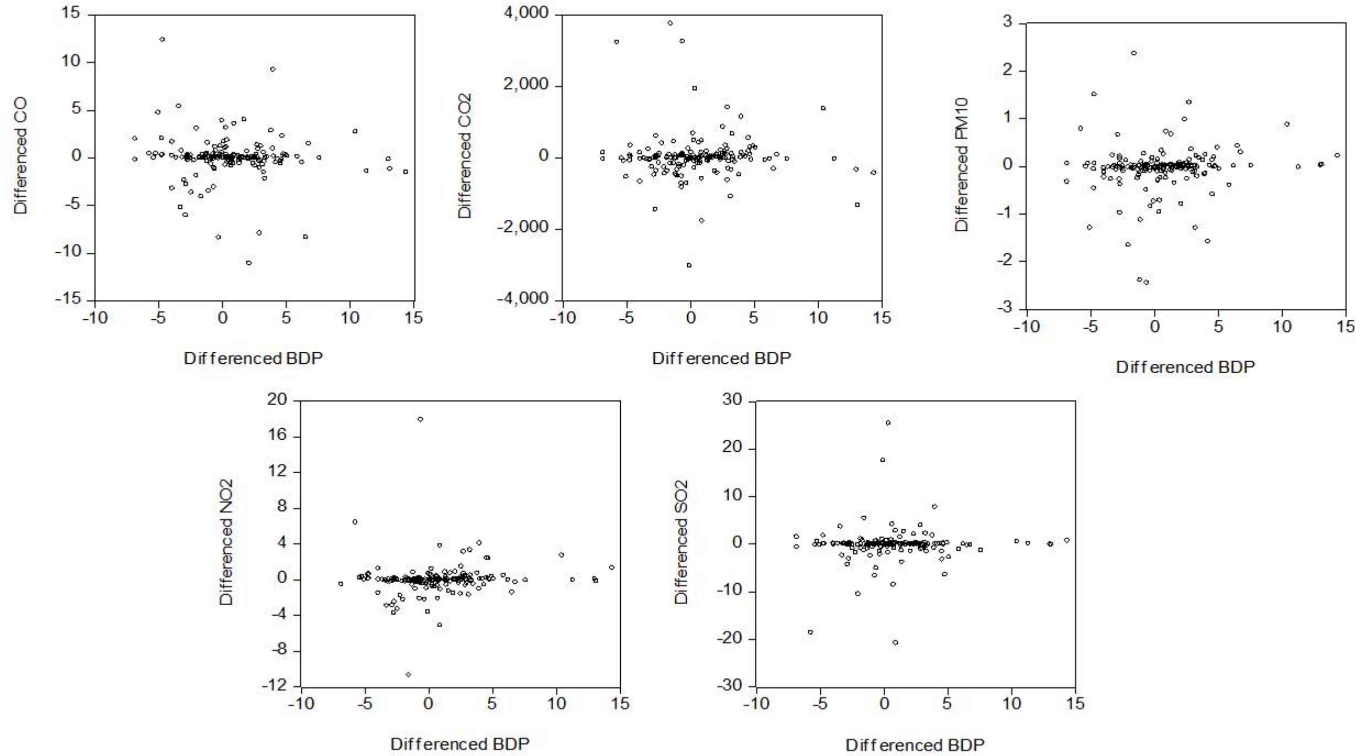

Figure 12-16. Scatter plots for pollutants in differences, in kg per capita versus GDP per capita, panel data (Source: author's calculation.)

ISSN 1332-9049

Before estimating different specifications of the EKC relationship, unit root tests have been performed for every variable. Unit root tests assume non-stationarity in the null hypothesis. The alternative hypothesis differs depending upon the test. Some tests assume that every observed unit has its own unit root value, while others assume the same value of the unit root parameter; some tests are asymptotically dependent on *N* and/or *T* (see Verbeek, 2002 for detailed discussion). Since this research is dealing with small number of observed units (*N*) and small number of time periods (*T*), tests which assume $N/T \to 0$ such as LLC are preferable compared to others (see Hlouskova and Wagner, 2006 for detailed comparison). Detailed results are shown in Tables 10 and 11, where it can be seen that all of the variables seem to be stationary.

Next, the following forms of the EKC relationship are observed:

$$POL_{it} = \alpha_i + \lambda_t + \beta_1 GDP_{it} + \beta_2 GDP_{it}^2 + \beta_4 PR_{it} + \varepsilon_{it}, \quad (10)$$

$$POL_{it} = \alpha_i + \lambda_t + \beta_1 GDP_{it} + \beta_2 GDP_{it}^2 + \beta_3 GDP_{it}^3 + \beta_4 PR_{it} + \varepsilon_{it}, \quad (11)$$

and

$$POL_{it} = \alpha_i + \lambda_t + \beta_1 GDP_{it} + \beta_4 PR_{it} + \delta D_{it} + \varepsilon_{it}, \quad (12)$$

where POL_{it} denotes pollutant per capita for county *i* in year *t*, GDP_{it} is GDP per capita of county *i* in year *t* and PR_{it} is pressure as previous defined, for county i in year t. If value of β_1 is found positive in any of the observed models, there exists a positive relationship between economic development in Croatia and the pollution. However, an EKC curve exists if the value of β_2 is negative (inverted U-curve). Finally, if the value of β_3 is different from zero, a cubic relationship exists, which is interpreted as changes of the U-shaped relationship between development and pollution. The fixed effects model was estimated for each pollutant for (9), (10) and (11) and *F* and Chi-square test were performed in order to compare fixed effects models to the pooled regression.

The results (test values) are shown in Table 12, where it can be seen that fixed effects are suitable for all pollutants in each model except for period effects for models where CO and PM_{10} are the pollutants.

Table 10. Unit root tests, constant and trend included in level equation, constant in first difference equation

Variable	GDP	Pressure	CO	CO_2	NO_2	PM_{10}	SO_2
			Level, constant and trend				
LLC	-12.8***	-7.49***	-12.25***	-8.31***	-20.98***	-9.58***	-10.32***
Breitung	3.22	-2.46***	-0.4	0.94	0.79	2.31	-1.36*
IPS	-1.32***	0.37	-1.55*	-0.48	-1.36*	-0.52	-0.85
ADF	77.67***	33.35	82.79***	59.32**	72.39**	61.76**	63.39**
PP	95.78***	30.7	141.01***	91.74***	85.09***	82.97***	83.98***
			First difference, constant				
LLC	-13.97***	-12.66***	-20.33***	-14.47***	-12.946***	-17.46***	-15.07***
IPS	-5.4***	-4.15***	-8.77***	-6.63***	-5.672***	-5.83***	-5.92***
ADF	115.73***	96.76***	162.11***	127.1***	119.264***	120.45***	123.65***
PP	122.36***	137.74***	217.77***	145.68***	163.51***	167.31***	152.82***

*, ** and *** denote statistical significance on 10%, 5% and 1%. LLC - Levin–Lin–Chu (2002) unit root test, Breitung - Breitung (2000) unit root test, IPS - Im–Pesaran–Shin (2003), ADF and PP denote Fisher-type tests using ADF and PP tests (Maddala and Wu (1999), Choi (2001)). This table provides results of unit root testing for level series with included constant and trend in the test equation (upper panel) and for series in first differences with included only constant in test equation. Optimal lag was chosen based upon Schwartz information criteria (as being the strictest one).

Table 11. Unit root tests, constant included in level equation, no deterministic variable included in first difference equation

Variable	GDP	Pressure	CO	CO_2	NO_2	PM_{10}	SO_2
			Level, constant				
LLC	0.76	0.85	-4.43***	-6.75***	-2.04**	-8.96***	-3.35***
IPS	1.44	4.03	-1.86**	-1.7	-1.17	-3.31***	-0.44
ADF	28.81	8.76	72.07***	69.79**	59.76**	83.49***	49.11
PP	23.51	5.74	88.58***	83.67***	63.20**	99.89***	50.66
			First difference, none				
LCC	-12.93***	-5.37***	-20.36***	-12.93***	-19.67***	-18.64***	-14.73***
ADF	183.93***	101.45***	253.25***	191.27***	205.87***	210.14***	207.38***
PP	173.19***	98.27***	269.8***	209***	228.22***	230.09***	214.8***

*, ** and *** denote statistical significance on 10%, 5% and 1%. LLC - Levin–Lin–Chu (2002) unit root test, Breitung - Breitung (2000) unit root test, IPS - Im–Pesaran–Shin (2003), ADF and PP denote Fisher-type tests using ADF and PP tests (Maddala and Wu (1999), Choi (2001)). This table provides results of unit root testing for level series with included constant in the test equation (upper panel) and for series in first differences with no deterministic variables included in test equation. Optimal lag was chosen based upon Schwartz information criteria (as being the strictest one).

Table 12. Results of comparison of fixed effects model to the pooled regression for models (9), (10) and (11)

Test/pollutant		CO	CO_2	NO_2	PM_{10}	SO_2
Cross-section F	Model (9)	40.48***	143.47***	70.48***	17.83***	29.91***
	Model (10)	40.65***	141.86***	70.83***	17.89***	29.63***
	Model (11)	40.39***	140.64***	70.19***	18.48***	28.54***
Cross-section Chi-square	Model (9)	342.53***	558.1***	433.69***	223.17***	295.94***
	Model (10)	344.19***	557.21***	435.61***	224.44***	295.44***
	Model (11)	344.18***	556.81***	435.16***	229.58***	290.85***
Period F	Model (9)	1.01	2.51**	1.94*	0.58	2.55**
	Model (10)	1.44	2.49**	2.31**	0.99**	2.65***
	Model (11)	1.4	2.33**	2.26**	1.18	2.6**
Period Chi-square	Model (9)	9.46	22.65***	17.69**	5.46	22.96***
	Model (10)	13.1*	22.6***	21.02***	9.29	23.95***
	Model (11)	13.14	21.37***	20.71***	11.12	23.62***
Cross-section and period F	Model (9)	30.09***	106.24***	51.90***	14.18***	23.95***
	Model (10)	29.89***	104.46***	51.83***	14.18***	23.92***
	Model (11)	29.69***	103.52***	51.37***	14.63***	23.09***
Cross-section and period Chi-square	Model (9)	348.84***	564.56***	438.89***	237.51***	313.18***
	Model (10)	348.77***	562.66***	439.74***	238.33***	313.97***
	Model (11)	348.74***	562.19***	439.3***	243.49***	309.56***

*, ** and *** denote statistical significance on 10%, 5% and 1%.

Next, selected fixed effects models are compared to random effects models via Hausman test given in (8). Test values are given in table 12. It can be seen that the cross section fixed effects model is appropriate for: model (9) for all pollutants, and models (10) and (11) for all pollutants except CO; and no random effects were found in period specification of the model. Thus, the majority of the estimated models will be with the assumption of fixed effects because the estimators will be consistent. This is in line with previously stated facts of social and economic differences between the counties (industry, tourism, population growth/decline, etc.), which this approach controls for (individual heterogeneity). The cross-section fixed effects capture counties' individual characteristics which could contribute to differences between them, such as being the capital city of the country or relying heavily on tourism as income generator; or when individual county carried out greater projects regarding the pollution reduction and/or waste management. Time fixed effect when included, could differentiate between periods after the crisis of 2007-2008 and the recovery in years later, which could have affected the dependent variable, i.e. pollution could have been smaller in the crisis year due to decline of industry and manufacturing or decline of automobile purchases which lowered the total air pollution.

Based upon the results from tables 12 and 13, appropriate models have been estimated for every pollutant. Detailed results are given in Table 14. There are several conclusions which can be drawn by observing the results. First of all, in model (9), the variable GDP per capita is significant for all variables except SO_2. This means that to some extend there exists a relationship between economic development and level of pollution in Croatia. However, the value of $\hat{\beta}_1$ is positive for all pollutants with exception of CO, which means that increase in GDP per capital leads to increase of the pollution. This is in line with results in Jošić et al. (2016). The negative coefficient for CO pollutant model (9) could be a result of stopping the production of aluminium, pulp and paper in Croatia after the crisis in 2008. Thus, although the income per capita has slightly increased in the observed period, the CO emissions dropped and in that way a negative relationship exists between those two variables. By adding the quadratic term of income per capita (model 10), it is only significant for pollutants NO_2 and PM_{10}. This is in line with Mor and Jindal (2012). The positive values are in accordance with the research of Jošić et al. (2016). Finally, model (11) has significant variables only for PM_{10}. This means that a cubic relationship could exist between development and pollution in this case. With the positive and negative values of betas corresponding to income

Table 13. Results of Hausman test for models (9), (10) and (11)

Test/pollutant		CO	CO_2	NO_2	PM_{10}	SO_2
Cross-section random	Model (9)	6.51**	0	12.59***	35.85***	27.89***
	Model (10)	2.66	0	0	36.05***	693.32***
	Model (11)	2.57	0	0	33.54***	0
Period random	Model (9)	-	0	0	-	0
	Model (10)	-	0	0	-	0
	Model (11)	-	0	0	-	0
Cross-section and period random	Model (9)	-	0	6.52**	-	6.98**
	Model (10)	-	0	0	-	11.67***
	Model (11)	-	0	0	-	0

*, ** and *** denote statistical significance on 10%, 5% and 1%. Zero values denote that no random effects were found.

and its transformations, there seems that a U-shaped curve exists up to a certain point of income per capita and afterwards an EKC (inverted U-shaped) curve is present for this pollutant. This is the so-called opposite N shape, and it is in line with Mor and Jindal (2012).

However, the results should be taken with some caution, due to small sample (regarding both *N* and *T*), due to unit root tests being valid asymptotically. Thus, all of the variables were differenced in order to dispose of any non-stationarity which could not have been detected in unit root testing. Next, models in Table 14 were re-estimated with differenced data and the results are shown in Table 15. It can be seen that now even more variables become insignificant. Only results for model (10) confirm that SO_2 could have the inverted U shape (EKC hypothesis) or the cubic relationship (model 11). These results are in line with Piłatowska and Włodarczyk (2017), where no short-term relationship is found for similar CEE countries, such as Estonia, Romania and Slovenia.

Moreover, since Croatia has joined EU in 2013, an additional model will be observed by adding a binary variable equal to unit value for years 2013-2016. The best model chosen for each pollutant in table 14 will be extended with the mentioned binary variable in order to explore effects of EU legislation which Croatia had to implement into its existing laws and the implementation of the 7th Environment Action Programme (EAP) of European Commission. Therefore, models (9), (10) and (11) will be extended as:

Table 14. Results of estimation of models (9), (10) and (11) for all pollutants

Estimations	CO	CO_2	NO_2	PM_{10}	SO_2
			Model (9)		
$\hat{\alpha}$	2.29	4.82	-5.43	-32.67***	0.62
$\hat{\beta}_1$	-1.67*	1.13*	2.9***	2.97**	2.65
$\hat{\beta}_4$	0.3	-2.06	0.13	14.06***	-2.91
$\bar{R}^2$	0.86	0.96	0.91	0.72	0.84
			Model (10)		
$\hat{\alpha}$	28.53*	7.64	20.72	25.21	20.33
$\hat{\beta}_1$	-30.96*	-1.79	-24.24*	-61.65***	-17.82
$\hat{\beta}_2$	0.04	-2.19	-1.11	13.47***	-3.85
$\hat{\beta}_4$	8.29	0.83	7.7**	18.3***	5.81
$\bar{R}^2$	0.86	0.96	0.91	0.73	0.84
			Model (11)		
$\hat{\alpha}$	-49.03	21.8	43.4	387.29*	34.25
$\hat{\beta}_1$	98.92	6.79	-62.14	-652.90**	-41.08
$\hat{\beta}_2$	0.1	-6.48*	-1.15	13.18***	-3.87
$\hat{\beta}_3$	-64.18	-16.63	28.84	348.22*	18.78
$\hat{\beta}_4$	13.45	5.45	-3.92	-61.23*	-2.41
$\bar{R}^2$	0.86	0.86	0.91	0.74	0.83

*, ** and *** denote statistical significance on 10%, 5% and 1%.   denotes the adjusted coefficient of determination.

Table 15. Results of estimation of models (9), (10) and (11) for all pollutants, differenced variables

Estimations	CO	CO_2	NO_2	PM_{10}	SO_2
			Model (9)		
$\hat{\alpha}$	-0.047	12.811	-0.111	-0.064	-0.281
$\hat{\beta}_1$	-0.039	1.684	0.042	0.005	0.098
$\hat{\beta}_4$	-0.029	-2.525	-0.016	0.001	0.039
$\bar{R}^2$	0.043	0.015	0.074	0.118	0.045
			Model (10)		
$\hat{\alpha}$	-0.136	18.490	-0.167	-0.091*	-0.007
$\hat{\beta}_1$	-0.103	5.761	0.001	-0.014	0.295*
$\hat{\beta}_2$	0.011	-0.684	0.007	0.003	-0.033*
$\hat{\beta}_4$	-0.028	-2.568	-0.016	0.0001	0.037
$\bar{R}^2$	0.049	0.186	0.078	0.13	0.068
			Model (11)		
$\hat{\alpha}$	-0.377	-39.711	-0.375	-0.12**	0.443
$\hat{\beta}_1$	-0.016	26.831	0.077	-0.004	0.132
$\hat{\beta}_2$	0.04*	6.491	0.032*	0.001	-0.089**
$\hat{\beta}_3$	-0.003	-0.696	-0.002	-0.0003	0.005*
$\hat{\beta}_4$	-0.028	-2.486	-0.015	0.001	0.037
$\bar{R}^2$	0.066	0.198	0.094	0.135	0.091

*, ** and *** denote statistical significance on 10%, 5% and 1%.   denotes the adjusted coefficient of determination.

$$POL_{it} = \alpha_i + \lambda_t + \beta_1 GDP_{it} + \beta_4 PR_{it} + \delta D_{it} + \varepsilon_{it}, \quad (12)$$

$$POL_{it} = \alpha_i + \lambda_t + \beta_1 GDP_{it} + \beta_2 GDP_{it}^2 + \beta_4 PR_{it} + \delta D_{it} + \varepsilon_{it}, \quad (13)$$

and

$$POL_{it} = \alpha_i + \lambda_t + \beta_1 GDP_{it} + \beta_2 GDP_{it}^2 + \beta_3 GDP_{it}^3 + \beta_4 PR_{it} + \delta D_{it} + \varepsilon_{it}, \quad (14)$$

where D_{it} denotes binary variable for county *i* in time *t*, equal to 1 for years 2013-2016 and 0 otherwise. Model (12) is estimated for CO, CO_2 and SO_2, model (13) for NO_2 and model (14) for PM_{10}, with the results shown in Table 16. It can be seen that the binary variable is significant for all pollutants except CO. Its value is negative, which means that the Croatia's accession to EU had a negative impact on pollution, i.e. pollution has diminished in the last several years. The impact was the greatest for the SO_2 pollutant.

Results in Table 16 have been re-estimated with differenced variables as well, with the results shown in Table 17. Now, every variable becomes insignificant in all models for all pollutants. Thus, by observing data in differences, which could be interpreted as short-term analysis, no significant results were found. Moreover, due to having a small number of yearly data available for this study, the results should be observed with caution.

Table 16. Results of estimation of models (12), (13) and (14) for all pollutants

Estimations	CO	CO_2	NO_2	PM_{10}	SO_2
$\hat{\alpha}$	5.9	4.56**	14.74	458.65**	0.77
$\hat{\beta}_1$	-1.56	0.39	-20.02	-768.65**	0.15
$\hat{\beta}_2$	-1.68	-1.2	0.61	8.46***	-0.57
$\hat{\beta}_3$	-	-	6.22*	410.41**	-
$\hat{\beta}_4$	-	-	-	-72.29**	-
$\hat{\delta}$	-0.09	-0.07***	-0.12***	-0.2**	-0.22***
$\bar{R}^2$	0.86	0.96	0.91	0.75	0.83

*, ** and *** denote statistical significance on 10%, 5% and 1%.

Table 17. Results of estimation of models (12), (13) and (14) for all pollutants, differenced variables

Estimations	CO	CO_2	NO_2	PM_{10}	SO_2
$\hat{\alpha}$	-0.267	6.947	-0.357	0.732	0.121
$\hat{\beta}_1$	-0.119	-13.119	0.084	0.004	0.154
$\hat{\beta}_2$	0.008	0.725	0.023	0.005	-0.013
$\hat{\beta}_3$	-	-	-0.002	-0.0003	-
$\hat{\beta}_4$	-	-	-	-0.006	0.036
$\hat{\delta}$	0.382	17.721	0.139	0.124	-0.565
$\bar{R}^2$	0.032	0.142	0.062	0.124	0.028

*, ** and *** denote statistical significance on 10%, 5% and 1%.

Since some research explains that effects of economic development on pollution decreasing is not instantaneous (see Halkos, 2003 or Taguchi, 2012), Granger test of causality between each pollutant and GDP is observed additionally. This is conducted in order to test for lagged effects of GDP on the pollution. Results are shown in table 18, where it can be seen that at lag 1 (one year) no Granger causality can be confirmed on usual levels of significance. At lag 2, GDP Granger causes NO_2 (at 5% significance level), while pollutants CO_2 and PM_{10} Granger cause GDP (again, at 5%). This can be interpreted as economic development having impact on NO_2 emissions with a two year lag, which could have been a result of Petrokemija lowering ammoniac production in 2009, HEP Group (Hrvatska Elektroprivreda) investing over 17 mil Euros into TE Plomin to lower nitrogen oxide emissions in 2014 and similar investments into more sustainable production and development in Croatia. Since Croatia ratified the Kyoto Protocol in 2007, emissions of CO_2 are being lowered every year in order to reach the goal by 2020. It is expected that all pollutants will drop even more due to European Parliament and Council signing the new National Emissions Ceilings (NEC) Directive, which entered into force on 31st December 2016, as well as ratifying the Gothenburg Protocol. By focusing on the Dumitrescu-Hurlin (2012) test, the GDP causes only NO_2

and SO_2 with one year lag apart (10% and 5%). Thus, there is weak evidence of the observed causalities between the GDP and pollution in the observed period.

If the same analysis is conducted over the differenced data (please see Table 19), no causality could be found for any pollutant and GDP. Again, results should be taken with some caution due to small number of time series observations.

Table 18. Results of Hausman test for models (9), (10) and (11) Granger causality test between pollution and economic development, variables in levels

Test/pollutant	Lag	CO	CO_2	NO_2	PM_{10}	SO_2
			Stacked data Granger causality			
GDP → POL	1	0.002	0.228	0.474	0.078	0.192
	2	0.336	1.962	4.415**	0.293	0.645
POL → GDP	1	0.588	1.217	0.049	0.819	0.086
	2	1.451	4.007**	2.153	3.823**	0.108
			Dumitrescu-Hurlin (2012) test			
GDP → POL	1	1.702	1.478	4.492***	2.384	3.779**
POL → GDP	1	1.563	2.218	2.111	2.027	2.589

GDP → POL denotes causality test where GDP is cause and pollution is consequence. POL → GDP denotes test where pollution is cause and GDP is consequence. *, ** and *** denote statistical significance on 10%, 5% and 1%. Dumitrescu-Hurlin (2012) test was tested up to only lag 1 due to insufficient number of data for lag 2.

Table 19. Granger causality test between pollution and economic development, variables in differences

Test/pollutant	Lag	CO	CO_2	NO_2	PM_{10}	SO_2
			Stacked data Granger causality			
GDP → POL	1	0.002	0.228	0.474	0.078	0.192
	2	0.336	1.962	4.415**	0.293	0.645
POL → GDP	1	0.588	1.217	0.049	0.819	0.086
	2	1.451	4.007**	2.153	3.823**	0.108

GDP → POL denotes causality test where GDP is cause and pollution is consequence. POL → GDP denotes test where pollution is cause and GDP is consequence. *, ** and *** denote statistical significance on 10%, 5% and 1%.

CONCLUSIONS

Since the beginning of 1990s, opinions on the relationship between economic development and pollution have been getting more profound. The EKC curve is being tested and modified in order to explore the consequences of economic growth on environment and the sustainable development. Sustainable development, according to the EKC theory, should not present a problem when an economy reaches a certain level of income.

This paper explored several functional forms of the EKC relationship for five different pollutants and economic development in Croatia. Since previous literature on this subject is scarce, basic information for Croatian counties could have been obtained in this study. The results indicate that a weak positive linear relationship exists between the majority of pollutants and income in Croatia by observing data in levels. This is contrary to the EKC theory. However, these conclusions could be a result of the time sample period, which included years in the economic crisis and afterwards. Since the available sample period was relatively short, the results could be also interpreted as the short run dynamics. Other studies which have more available data observe the short and long run dynamics simultaneously. Some other shortfalls of the study were as follows. Only yearly data could have been observed, due to measurement of the pollutants. This limits the results and their interpretations, due to possibility of not finding meaningful relationship due to having a small sample. Future work should extend the existing sample to re-evaluate the results. However, the initial results here are in line with previous research of Croatia regarding the short term, which gives hope to obtaining some relevant information on the EKC relationship. Moreover, only air pollution was observed, again due to availability of data. It would be interesting to observe other forms of pollution (such as water and ground pollution; which are important, especially in tourist-oriented counties).

Several recommendations can be given. A greater volume data is available today on the future plans, actions and the results from many different government agencies and other bodies. Thus, citizens of a country can get easier informed about the whole process of achieving the sustainable development, not only in tourism sector, but for other sectors of the economy. By being more informed, citizens and non-government institutions could make more pressure on the general and local governments to enhance environmental regulations, plans and actions to achieve the goals. Next, the utilization of European Union funds for sustainable development, tourism and economy should be enhanced. As of now, Croatia utilizes very little percentage of available funds available (European Commission, 2019 states that the spent/carried out sources out of planned were merely 1% in 2015, 3% in the following year, with 9% and 17% in 2017 and 2018). Thus, greater improvement of sustainable development overall, especially for the less developed counties could be obtained via the EU funding. In that way, environmentally friendly industries could be developed in future. Moreover, a lot of problems which were generated in tourism dependent counties in the late 1990s and early 2000s, such as the non-planning of infrastructure when building the accommodation capacities have to be sanitized as well (for details, please see Institute for Tourism in Croatia, 2016 or Škrinjarić, 2018). Finally, taxes on pollution could be one of the answers, in order to make somewhat pressure on major industry pollutants, with subsidies given to environmentally oriented firms.

Future research should expand the time span of data in order to compare the results with this research. Moreover, since tourism plays an important role in Croatia and its GDP, pollution pressures and EKC relationship should be explored in this sector as well.

REFERENCES

Agras, J., Chapman, D. (1999) A dynamic approach to the Environmental Kuznets Curve hypothesis. Ecological Economics, 28, 267-277. DOI: http://dx.doi.org/10.1016/S0921-8009(98)00040-8

Ahmad, N., Du, L., Lu, J., Wang, J., Li, H.-Z., Zaffar Hasmi, M. (2017) Modelling the CO_2 emissions and economic growth in Croatia: is there any environmental Kuznets curve? Energy, 123 (2017), 164-172.

Akbostanci, E., Türüt-Asik, S, Tunc, G. I. (2009) The relationship between income and environment in Turkey: Is there an environmental Kuznets curve? Energy Policy, 37, 861-867. DOI: http://dx.doi.org/10.1016/j.enpol.2008.09.088

Alkier Radnić, R. (2003) Marketinški aspekti razvoja turističke destinacije (Marketing aspects of tourist destination development). Tourism and hospitality management, 9 (2), 231-246.

Allard, A., Takman, J., Uddin, G. S., Ahmed, A. (2017) The N-shaped environmental Kuznets curve: an empirical evaluation using a panel quantile regression approach. Environmental Science and Pollution Research, 25, 5848–5861.
DOI: https://doi.org/10.1007/s11356-017-0907-0

Archibald, S. O., Bochniarz, Z., Gemma, M., Srebotnjak, T. (2009) Transition and sustainability: Empirical analysis of Environmental Kuznets Curve for water pollution in 25 Countries in Central and Eastern Europe and the Commonwealth of Independent States. Environmental Policy and Governance, 19, 73-98.
DOI: http://dx.doi.org/10.1002/eet.499

Arellano, M. (2003) Panel data econometrics. Oxford: Oxford University Press.

Arrow, K. Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C. S., Jansson, B.-O., Levin, S., Mäler, K.-G., Perrings, C. A., Pimentel, D. (1995) Economic Growth, Carrying Capacity and the Environment. Science, 268, 520-521.
DOI: http://dx.doi.org/10.1126/science.268.5210.520

Auffhammer, M., Carson, R. T., Garín-Muñoz, T., Rich, C. S. (2001) Exploring structural differences in CO_2 emissions of China's provinces. San Diego: Department of Economics, University of California.

Barbier, E., Markandya, A., Pearce, D. (1990) Sustainable agricultural development and project appraisal. European Review of Agricultural Economics, 17 (2), 181-196.
DOI: http://dx.doi.org/10.1093/erae/17.2.181

Breitung, J. (2000) The local power of some unit root tests for panel data. In: Baltagi, B. H., eds. Advances in econometrics, Volume 15: Nonstationary panels, panel cointegration, and dynamic panels. Amsterdam: JAI Pres.

Brooks, C. (2008) Introductory econometrics for finance. 2nd edition. Cambridge: Cambridge University Press.

Choi, I. (2001) Unit root tests for panel data. Journal of International Money and Finance, 20, 249–272.

Cole, M. A., Rayner, A. J., Bates, J. M. (1997) The environmental Kuznets curve: An empirical analysis. Environment and Development Economics, 2, 401–416.
DOI: http://dx.doi.org/10.1017/S1355770X97000211

Coondoo, D., Dinda, S. (2002) Causality between income and emission: a country group-specific econometric analysis. Ecological Economics, 40, 351-367.
DOI: http://dx.doi.org/10.1016/S0921-8009(01)00280-4

Costantini V., Martini, C. (2006) A modified Environmental Kuznets Curve for sustainable development assessment using panel data. Rome: Department of Economics, University of Roma Tre.

Croatian Agency for the Environment and Nature (2017) The Republic of Croatia 2017 Informative Inventory Report (1990-2015). Zagreb: Croatian Agency for the Environment and Nature.

Croatian Agency for the Environment and Nature (2018) Browser of Registry of Environmental Pollution. [Online] Zagreb: Croatian Agency for the Environment and Nature. Available at: http://www.haop.hr/en [Accessed 1 May 2018].

Croatian Bureau of Statistics (2018) PC-Axis databases. [Online] Zagreb: Croatian Bureau of Statistics. Available at: http://www.dzs.hr/en [Accessed 1 May 2018].

Croatian Chamber of Economy (2016) Counties – great economic differences on small area. Zagreb: Croatian Chamber of Economy.

Dijkgraaf, E., Vollebergh, H. R. J. (2005) A test for parameter homogeneity in CO_2 panel EKC estimations. Environmental & Resource Economics, 32, 229-239.

Dinda, S., Coondoo, D. (2006) Income and emission: A panel data-based cointegration analysis. Ecological Economics, 57, 167-181.
DOI: http://dx.doi.org/10.1016/j.ecolecon.2005.03.028

Dumitrescu, E.-I., Hurlin, C. (2012) Testing for granger non-causality in heterogeneous panels. Economic Modelling, 29 (4), 1450-1460.

European Commission (2018) Press release "In 2017, CO_2 emissions in the EU estimated to have increased compared with 2016". [Online] Brussels: European Commission. Available at: http://ec.europa.eu/eurostat/web/products-press-releases/-/8-04052018-BP [Accessed 1 June 2018]

European Commission (2019) European structural and investment funds, data for Croatia. [Online] Brussels: European Commission. Available at: https://cohesiondata.ec.europa.eu/countries/HR [2 [Accessed March 2019]

Galeotti, M., Lanza, A. (2005) Desperately seeking environmental Kuznets. Environmental Modelling & Software, 20, 1379-1388.
DOI: http://dx.doi.org/10.1016/j.envsoft.2004.09.018

Gangadharan, L., Valenzuela, M. R. (2001) Interrelationships between income, health and the environment: extending the Environmental Kuznets Curve hypothesis. Ecological Economics, 36, 513-531.
DOI: http://dx.doi.org/10.1016/S0921-8009(00)00250-0

Greene, W. H. (2003) Econometric analysis. 5th edition. New York: Pearson.

Grossman, G. E., Krueger, A. B. (1991) Environmental effects of a NAFTA, National Bureau of Economic Research, Working Paper 3914. NBER, MA. Massachusetts: The National Bureau of Economic Research.

Grossman, G. M., Krueger, A. B. (1995) Economic growth and the environment. Quarterly Journal of Economics, 1, 353-377.
DOI: http://dx.doi.org/10.2307/2118443

Grossman, G., Kreuger, A. (1996) Economic growth and the environment. Quarterly Journal of Economics, 110 (2), 353-377.
DOI: http://dx.doi.org/10.2307/2118443

Hlouskova, J., Wagner, M. (2006) The performance of panel unit root and stationarity tests: Results from a large simulation study. Econometric Reviews, 25 (1), 85-116.
DOI: http://dx.doi.org/10.1080/07474930500545504

Im, K. S., Pesaran, M. H., Shin, Y. (2003) Testing for unit roots in heterogeneous panels. Journal of Econometrics 115, 53–74.

Institute for Tourism (2016) Preliminary report of Croatian sustainable tourism observatory focal area: Adriatic Croatia. Zagreb: Institute for Tourism. Available at: http://iztzg.hr/UserFiles/File/CROSTO-Preliminary-Report-for-UNWTO.pdf [Accessed 2 March 2019]

Iwata, H., Okada, K., Samreth, S. (2011) A note on the environmental Kuznets curve for CO_2: A pooled mean group approach. Applied Energy, 88, 1986-1996.
DOI: http://dx.doi.org/10.1016/j.apenergy.2010.11.005

Jošić, H., Jošić, M., Janečić, M. (2016) Testing the environmental Kuznets curve in the case of Croatia. Notitia - journal for sustainable development, 2 (2), 31-47.

Kasman, A., Selman Duman, Y. (2015) CO_2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: A panel data analysis. Economic modelling, 44 (2015), 97-103.

Kružić, N. (2004) Turizam i okoliš (Tourism and environment). Journal of Tourism and Hospitality Management, 10 (2), 67-159.

Kuznets, S. (1955) Economic growth and income inequality. American Economic Review, 49, 1-28.

Levin, A., C.-F., Lin, Chu, C.-S. J. (2002) Unit root tests in panel data: Asymptotic and finite-sample properties. Journal of Econometrics, 108, 1–24.

Liddle, B. (2015) Urban transport pollution: Revisiting the Environmental Kuznets Curve. International Journal of Sustainable Transportation, 9 (7), 502-508. DOI: http://dx.doi.org/10.1080/15568318.2013.814077

List, J. A., Gallet, C. A. (1999) The environmental Kuznets curve: does one size fit all? Ecological Economics, 31, 409-423. DOI: http://dx.doi.org/10.1016/S0921-8009(99)00064-6

Maddala, G. S., Shaowen Wu (1999) A comparative study of unit root tests with panel data and a new simple test. Oxford Bulletin of Economics and Statistics, 61, 631-652.

Maddala, G. S. (2001) Introduction to econometrics. 3rd edition. New Jersey: John Wiley & Sons LTD.

Mor, S., Jindal, S. (2012) Estimation of Environmental Kuznets Curve and Kyoto Parties: A panel data analysis. International Journal of Computational Engineering & Management, 15 (1), 2230-7893.

Niu, S., Ding, Y., Niu, Y., Li, Y., Luo, G. (2011) Economic growth, energy conservation and emissions reduction: A comparative analysis based on panel data for 8 Asian-Pacific countries. Energy Policy, 39, 2121-2131. DOI: http://dx.doi.org/10.1016/j.enpol.2011.02.003

Panayotou, T. (1993) Empirical tests and policy analysis of environmental degradation at different stages of economic development (Working Paper WP238). Geneva: Technology and Labour Office.

Pezzey, J. (1989) Economic analysis of sustainable growth and sustainable development (Environmental department working paper 15). Washington, DC: The World Bank.

Physical planning department of Bjelovar-Bilogora county (2015) Strategic study of physical planning effects of Bjelovar-Bilogora county. Bjelovar: Physical planning department of Bjelovar-Bilogora county.

Physical planning department of Istria county (2017) Report on status in place of Istria county for 2013-2016. Pula: Physical planning department of Istria county.

Piłatowska, M., Włodarczyk, A. (2017) The environmental Kuznets curve in the CEE countries – the threshold cointegration approach. Argumenta Oeconomica, 39 (2), 307-340.

Roca, J., Padilla, E., Farré, M., Galletto, V. (2001) Economic growth and atmospheric pollution in Spain: Discussing the environmental Kuznets curve hypothesis. Ecological Economics, 39, 85–99. DOI: http://dx.doi.org/10.1016/S0921-8009(01)00195-1

Selden, T., Song, D. (1994) Environmental quality and development: Is there a Kuznets Curve for Air Pollution Emissions? Journal of Environmental Economics and Management, 27 (2), 147-162. DOI: http://dx.doi.org/10.1006/jeem.1994.1031

Shafik, N., Bandyopadhyay, S. (1992) Economic growth and environmental quality: Time series and cross-country evidence, background paper for World Development Report 1992. Washington, DC: The World Bank.

Song, T., Zheng, T., Tong, L. (2008) An empirical test of the environmental Kuznets curve in China: A panel cointegration approach. China Economic Review, 19, 381–392. DOI: http://dx.doi.org/10.1016/j.chieco.2007.10.001

Stern, D., Common, M. S., Barbier, E. (1996) Economic growth and environmental degradation: The environmental Kuznets curve and sustainable development. World Development, 24 (7), 1151-1160. DOI: http://dx.doi.org/10.1016/0305-750X(96)00032-0

Stern, D. I., Common, M. S. (2001) Is there an environmental Kuznets curve for sulfur? Journal of Environmental Economics and Management, 41, 162–178. DOI: http://dx.doi.org/10.1006/jeem.2000.1132

Stern, D. I. (2004) The rise and fall of the Environmental Kuznets Curve. World Development, 32, 1419-1439. DOI: http://dx.doi.org/10.1016/j.worlddev.2004.03.004

Škrinjarić, T. (2018) Evaluation of environmentally conscious tourism industry: Case of Croatian counties. Tourism, 66 (3), 254-268.

Taguchi, H. (2012) The Environmental Kuznets Curve in Asia: The Case of Sulphur and Carbon Emissions. Asia-Pacific Development Journal, 19 (2), 77-92. DOI: http://dx.doi.org/10.18356/9eb232aa-en

Verbeek, M. (2002) A guide to modern econometrics. London: John Wiley & Sons.

Wooldridge, J. M. (2002) Econometric analysis of cross section and panel data. New York: MIT Press.

Xuemei, L. (2005) Explaining the relationship between CO_2 emissions and national income – The role of energy consumption. Economics Letters, 87, 325–328.