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RESEARCH ARTICLE

The impact of economic structure to the environmental Kuznets curve (EKC) hypothesis: evidence from European countries

Eyup Dogan[1] · Roula Inglesi-Lotz[2]

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Abstract

The purpose of this study is to examine the role of economic structure of European countries into testing the Environmental Kuznets Curve (EKC) hypothesis for European countries for the period 1980 to 2014. This study is inspired by the work of Lin et al. (J Clean Prod 133:712–724, 2016), which made the first effort to investigate the phenomenon looking only at African countries. The main finding of the study is that the overall economic growth is the factor with which CO_2 emissions exhibit an inverted U-shaped relationship in the studied country group. On the contrary, when using their industrial share as a proxy to capture the countries' economic structure, the EKC hypothesis is not confirmed – but a U-shaped relationship is confirmed. The industrial share decreases emissions through the development and absorption of technologies that are energy efficient and environmental friendly. The EKC hypothesis is confirmed when the aggregate GDP growth is considered, taking into account the improvement of the overall economic conditions of the countries regardless of the economic structure and role of industrialization.

Keywords EKC · Economic structure · Industrialization · Europe

Introduction

Policy makers globally make an effort at implementing appropriate policies in order to both promote economic development and environmental conservation taking into consideration the detrimental effects of climate changing, toward a sustainable future. However, "one-size-fits-all" approaches will not achieve the desired effects for all: countries dependent highly on the agricultural sector are more vulnerable to climatic fluctuations and emit less than more industrialized economies that have higher level of emissions and do not depend on weather-related conditions. Based on the EKC hypothesis, after reaching a threshold, the relationship between environmental degradation and economic development becomes negative – exhibiting a synergy thus in improving living standards and income levels while simultaneously decreasing emissions.

In the energy literature, consensus has not been reached into answering whether the EKC hypothesis is confirmed or not and for which types of countries, but most studies have measured economic growth in aggregate without considering the differences within their economic structure. Choi (2014) discusses that agriculture- or industrial-led economic growth do not give countries the same characteristics in many aspects, even more so with regard to their impacts to energy and environmental patterns. Kaika and Zervas (2013) also explain that omitting taking into account the different composition of GDP among countries is a serious disadvantage of the majority of the literature. The Europe has target of an average of 11.8% reduction in emissions by the end of the first commitment period of the Kyoto protocol. In addition, the Europe aims to reduce emissions by an average of 20% below 1990 levels by 2020 according to Doha Amendment. Moreover, the Europe has projected to decrease emissions by 40% against to 1990 levels by 2030. Because of these commitments and projections, it is important to understand the determinants of emissions and the validity of EKC hypothesis in European countries.

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✉ Eyup Dogan
eyup.dogan@agu.edu.tr

Roula Inglesi-Lotz
roula.inglesi-lotz@up.ac.za

[1] Department of Economics, Abdullah Gul University, Office A210, Kayseri, Turkey

[2] Department of Economics, University of Pretoria, Pretoria, South Africa

The purpose of this study is to examine the role of the economic structure of EU countries into testing the Environmental Kuznets Curve (EKC) hypothesis. Lin et al. (2016) made the first effort to investigate the phenomenon looking only at African countries by using the STIRPAT empirical model and the fully modified ordinary least squares (FMOLS) estimation techniques. Their study does not find any significant impact of the economic structure, but their focus only on developing, primarily agricultural; economies might have driven the consequences. Their suggestion, based on the results, "future research should not focus much on explaining the validity or otherwise of the EKC hypothesis, but on determining the conditions under which the EKC curve holds true". In this line, the fundamental contribution of this study to the existing literature is to adopt the theoretical framework by Lin et al. (2016). In this line, the current study also relies on the STIRPAT model and FMOLS technique to analyze the determinants of CO_2 emissions and the validity of EKC hypothesis for European countries considering the means of economic structure. The second section presents the related studies, the third section describes theoretical framework, the forth section explains the data, the fifth section provides econometric approaches, the sixth section shows empirical results, and the last section discusses conclusions and policy implications.

Literature review

The relationship between economic development (measured in income levels) and the environment is divided into the scale effect, the technique effect, and the composition effect (Brock and Taylor 2005):

- Scale effect: "if the scale of economic activities increases proportionally as the economy grows, environmental pollution will increase with economic growth"
- Composition effect: "the effect of economic growth on the environment could be positive or negative depending on the changes in the composition of production of a country"
- Technique effect: "the environmental impact of economic growth may depend on changes in production techniques". (Lin et al. 2016)

The specific linkage between economic growth and environmental quality or degradation has been extensively discussed in the recent literature. One of the theoretical foundations of the mechanics of this relationship is founded on the paper by Kuznets (1955). According to this hypothesis, economic development measured usually by income per capita is linked with an increase in environmental degradation measured usually in the level of some form of air pollution (emissions) until a certain level, after which the relationship has a negative sign (Shafik 1994). The specific threshold is considered to represent the level of such economic affluence or prosperity that after that, the economies have the capacity to reduce pollution. Under this theoretical framework, economic growth can be promoted through energy intensive economic sectors and activities that are oftentimes emission producing and environmentally harmful. The literature has shown interest and trust in the Environmental Kuznets Curve (EKC) hypothesis through the years. In the beginning of the 1990s, Grossman and Krueger (1995) were the pioneers of the literature (see Sinha et al. (2019); Ozcan and Ozturk (2019) for an extensive discussion of the phenomenon technically and theoretically). The hypothesis was examined for various air pollutants and other indicators of environmental degradation or quality, and the various studies focused on different countries over different time periods (Destek et al. (2018) provide a recent summary of studies). The importance of this hypothesis in recent years has been stressed in the literature due to the climate change's negative impacts as well as the challenging financial and socioeconomic conditions internationally.

In the literature, studies (Apergis and Ozturk 2015; Hao et al. 2016; Wang et al. 2016; Bilgili et al. 2016; Shahbaz et al. 2017; El Montasser et al. 2018) confirm the EKC hypothesis and hence an inverted U-shaped relationship between income per capita and emissions. Stokey (1998) in the late 1990s confirmed an inverted U-shaped relationship between income and pollution. Chow and Li (2014) and Horii and Ikefuji (2014) used CO_2 emissions as a proxy for environmental degradation and confirmed the EKC hypothesis. Other proxies for environmental degradation used is water pollution: Thompson (2014) examined the EKC with water pollution as the proxy for environmental quality for 30 countries, while Paudel et al. (2005) did the same, both finding evidence for the EKC hypothesis. Other studies, however, did not find sufficient evidence to confirm the EKC hypothesis, such as Perman and Stern (2003), Lee et al. (2010) for 97 countries and Stern (2004). Using sulfur dioxide (SO2) as the proxy for environmental quality, Harbaugh et al. (2002) could not confirm the EKC hypothesis for cities internationally. Stern and Common (2001) using the same environmental indicator also did not find enough evidence for the EKC in 74 countries globally from 1960 to 1990. Balsalobre-Lorente and Alvarez-Herranz (2016) find N-shaped pattern.

The confirmation of EKC depends on other factors intuitively such as natural resource availability, technological progress or access to technology, and quality of institutions. Recently, studies have also started including additional variables to proxy institutional quality; Zafar et al. (2013) included the trade liberalization and corruption in their analysis. These factors might affect the shape of the EKC and the threshold level across countries (Horii and Ikefuji 2014).

From a technical point of view, the results are sensitive also to variables added, specification of the model, environmental proxy, and dataset (Carson 2010). Recent literature argues that emissions are not the most representative proxy for the environmental status of a country. Degradation in soil, forestry growth, mining, and oil are also indications of environmental degradation; EKC might be confirmed for air pollution but not for resource endowments (Arrow et al. 1996). Hence, Destek et al. (2018) suggest the use of an "inclusive environmental variable" such as the *ecological footprint* (Wachernagel and Rees 1996). Except for Lin et al. (2016), studies taking into consideration the different sources of economic growth as a point of difference among countries are non-existent. Many countries depend mainly in one economic sector, for example, manufacturing, as well as in many cases the country's policies promote for example, further industrialization to boost economic growth and development in the area. As Lin et al. (2016) discuss the practical policy, recommendations are valuable from this view. Due to criticism on the sensitivity of EKC to changes in variables etc. and to strengthen the theoretical foundation of this study, here, we use the STIRPAT framework to examine the EKC.

Energy structures as well as energy intensities are important determinants of environmental degradation and have vital importance to direct energy-related pollution (He and Lin 2019). Wang et al. (2013) find that population size increase emissions while energy structure decrease emissions for China. On the other hand, Chen and Lin (2015) suggest that energy structure and population have a positive impact on carbon emissions for China. In addition, Wang et al. (2017) state that energy structure is vital affecting element to control carbon emissions for China. Lin et al. (2017) discuss that both population and energy intensity are the main determinants of carbon emissions for non-high income countries. Roy et al. (2017) found that energy intensity, energy structure, and population are statistically the significant influencing factors of emissions for India. Moreover, Ghazali and Ali (2019) state the importance of energy intensity for the environment.

Theoretical framework

Chertow (2008) states that the IPAT identity is a framework to describe what determines environmental patterns. The model explains how population, affluence, and technology are the major contributors of environmental changes (usually measured in emissions, either CO_2 or other air pollutants).

$$I = P\, x\, A\, x\, T \tag{1}$$

where I is proxy for environmental degradation (emissions), P is population growth, A is societal affluence (usually measured in GDP), and T is proxy for technology.

The IPAT model was criticized for its simplicity and the assumption that the elasticities of all parameters are each equal to one (Wang and Zhao 2015; Tursun et al. 2015). Dietz and Rosa improved the initial IPAT by proposing the STIRPAT model:

$$I_t = \alpha P_t^b A_t^c T_t^d e_t \tag{2}$$

where a represents the constant term, P, A, and T are the same as before, b, c, and d represent the elasticities of environmental impacts with respect to P, A, and T, respectively, and et is the error term and the subscript t denotes the year.

This paper follows the theoretical framework by Lin et al. (2016) which expanded the STIRPAT model to analyze the determinants of CO_2 emissions of selected European countries. This study conceptualizes the affluence of the STIRPAT model in both the total GDP of the countries and also the industrial value added to examine their impacts on CO2 emissions. In their study, Lin et al. (2016) expanded the STIRPAT equation by including the square of GDP, urbanization levels, and energy structure of the countries. As You (2011) mentions, the energy consumption structure of a country is an important factor in the effects of consumption to the emission levels of the country. The energy structure denotes the share of fossil fuels in total energy consumption.

Previous studies use aggregate GDP as measurement of GDP, and neglect its pattern and composition and their effects on the environment or include the industrialization effect as a separate determinant. In order to understand the impact of economic structure and not overall economic growth of the countries, we use two individual models as given below:

Model I:

$$lnCO_{2it} = \alpha_0 + \alpha_1 ln\ GDP_{it} + \alpha_2 lnES_{it} + \alpha_3 lnEI_{it} + \alpha_4 lnURB_{it} + \alpha_5 lnPOP_{it} + \alpha_6 lnGDP_{it}^2 + e_i \tag{3}$$

Model II:

$$lnCO_{2it} = \alpha_0 + \alpha_1 ln\ IND_{it} + \alpha_2 lnES_{it} + \alpha_3 lnEI_{it} + \alpha_4 lnURB_{it} + \alpha_5 lnPOP_{it} + \alpha_6 lnIND_{it}^2 + e_i \tag{4}$$

Data

Table 1 presents the variables of the study, describing their units of measure as well as sources, and Table 2 presents a summary of their descriptive statistics. The seven European countries: Austria, Bulgaria, Finland, France, the Netherlands, Sweden, and Turkey for the period 1980 to 2014. The countries and time period used for this analysis are selected based on the availability of the data. Even though the number of analyzed countries is less than the actual number of

Table 1 Definition of variables

Variable	Definition	Units of measure	Source
CO_2	CO_2 emissions	Metric ton	World Development Indicators
GDP	Gross domestic product	Constant 2010 US$	World Development Indicators
IND	Industry, value added	Constant 2010 US$	World Development Indicators
ES	Energy structure	Share of fossil fuels (percent)	World Development Indicators
EI	Energy intensity	Technology Index	US Energy Information Admin.
URB	Urbanization	Percent	World Development Indicators
POP	Population	Percent	World Development Indicators

European countries, we believe that the outcome of this study is a good representative because of the similar characteristics of European countries. Table 2 provides some descriptive statistics for the variables used in the analysis.

The average of carbon emissions, GDP per capita, industrial economic growth, energy structure, energy intensity, urbanization, and population growth (in their logarithmic form) are 5.01, 11.5, 10.9, 1.81, 0.79, 1.85, and 7.17, respectively. The relatively small gap between minimum and maximum values of the variables implies that there are no huge differences among the examined countries in terms of economic development, technology, energy consumption structure, and the rest of the factors (also seen in the relatively low standard deviation for all the variables).

Econometric methodology

Panel unit root tests

Before deciding on the appropriate estimation technique, we proceed with testing the stationarity characteristics of all the variables. In this study, we employ three tests that assume the series have different unit root process: Im-Pesaran-Shin (IPS) test (Im et al. 2003), Fisher-ADF and Fisher-PP tests (Choi 2001) following Lin et al. (2016).

Panel cointegration tests

In the case that the unit root tests' results indicate the existence of non-stationarity, the study proceeds with an examination of the existence of a long-run relationship among the variables via cointegration testing: Pedroni residual cointegration test (Pedroni 2004) and Kao residual cointegration test (Kao 1999). The Pedroni cointegration test evaluates seven statistics under the null hypothesis of no cointegration in two scenarios (intercept only, intercept and trend).

Panel long-run estimators

The fully modified OLS (FMOLS) long-run estimators are developed in a study by Philips and Hansen (1990) to control for long-run correlations between the cointegrated equation and stochastic regressor innovations. The estimators are asymptotically unbiased and hence, allowing for standard Wald tests for statistical inference. Liddle (2012) also explains that "the FMOLS uses a semi-parametric correction for endogeneity and residual autocorrelation, and the FMOLS estimator is a group mean or between group estimators that allows for a high degree of heterogeneity in the panel".

Empirical results

Panel unit root tests

Table 3 summarizes the results of the three panel unit root tests. It is shown that the variables are nonstationary at levels but become stationary when differences once at 1% level of significance. As discussed above, in this case, the next step of the analysis is the examination of the existence of a long-run relationship among the variables.

Panel Cointegration tests

Based on the results obtained through the panel cointegration tests, this study asserts that variables are cointegrated for both Model I and Model II. Under the Pedroni test, the null hypothesis of no cointegration is rejected for the panel PP, panel ADF, group PP, and group ADF, both under intercept only and intercept and trend scenarios (Table 4). Four out of seven

Table 2 Descriptive statistics

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Obs.
CO_2	5.01	4.84	5.70	4.59	0.32	245
GDP	11.5	11.5	12.4	10.4	0.51	245
IND	10.9	10.9	11.7	9.82	0.43	245
ES	1.81	1.86	1.99	1.47	0.14	245
EI	0.79	0.77	1.26	0.44	0.17	245
URB	1.85	1.86	1.95	1.64	0.06	245
POP	7.17	6.95	7.88	6.67	0.41	245

Data values are transformed into logaritmic form

Table 3 Results from panel unit root tests

	Variable	IPS	Fisher ADF	Fisher PP
Levels	CO_2	0.04	15.00	23.01
	GDP	1.99	6.76	4.45
	IND	1.53	5.24	6.01
	ES	1.05	20.50	42.62*
	EI	0.56	14.53	14.21
	URB	2.74	10.39	41.49*
	POP	3.20	4.46	21.79
First-Difference	CO_2	− 11.64*	138.04*	173.59*
	GDP	− 7.54*	80.28*	81.10*
	IND	− 9.59*	106.12*	109.03*
	ES	− 8.97*	103.08*	176.04*
	EI	− 10.45*	121.16*	154.21*
	URB	− 6.00*	63.65*	156.79*
	POP	− 3.60*	40.42*	19.33

Values are test statistics. * denotes for 1% level of statistical significance

Pedroni test statistics confirm the existence of cointegration. For robustness purposes, the results are tested with the Kao panel cointegration tests. The Kao test uses the ADF test type t-statistic to examine the same null hypothesis of no cointegration.

Table 5 presents the results of the Kao test, through which the null hypothesis of no cointegration is rejected at 5% significance level

Table 5 Results from Kao panel cointegration test

	t-stat	Prob.	Residual var.	HAC var.
Model I	− 7.86*	0.000	0.0003	0.0001
Model II	− 2.78*	0.002	0.0003	0.0002

Values are test statistics. * denotes for 1% level of statistical significance

All in all, there is consistency in findings that there is evidence of a long-run relationship among the variables examined for Model I and Model II

Panel long-run estimators

Results obtained from FMOLS and OLS with fixed effect are reported in Table 6. For robustness purposes, Table 6 presents the results of the FMOLS method as well as fixed-effect panel regression estimation. Although using the adjusted R-squared, one might assume the preferred specification is the conventional fixed effects that estimation might suffer from other types of econometrics problems that the FMOLS controls for as discussed in the Methodology section. The estimated parameters do not seem to differ between fixed effects and FMOLS, with regard to their statistical significance, sign, and magnitude.

Table 4 Results from Pedroni panel cointegration test

	Intercept only		Trend and intercept	
	Model I	Model II	Model I	Model II
Panel v	− 0.94	− 0.97	− 2.06	− 2.01
Panel rho	− 0.24	0.32	0.83	0.92
Panel PP	− 4.72**	− 3.87**	− 4.81**	− 3.85**
Panel ADF	− 4.42**	− 2.85**	− 4.63**	− 3.34**
Group rho	0.69	1 07	1.51	1.61
Group PP	− 4.57**	− 3.97**	− 4.56**	− 3.52**
Group ADF	− 3.61**	− 2.29**	− 3.75**	− 2.06*

Values are test statistics. ** and * denotes for 1% and 5% level of statistical significance

Model I shows the results of the model using total GDP to represent economic development of the countries, while Model II uses the industrial economic growth as the proxy of affluence. The main difference in the two models' results is that the EKC hypothesis cannot be confirmed in the Model II – because the sign of coefficient on GDP is negative and GDP^2 is positive while the coefficients for IND and IND^2 are negative and positive, respectively.

In both models, the coefficient of the energy structure (ES) is the highest (1.03 in model I and 1.08 in model II), concluding that 1% in the share of fossil fuels in the energy mix will increase the level of emissions by 1.03% (or 1.08%), ceteris paribus. These results confirm the hypothesis that the use of fossil fuels is the main contributing factor to the increases in emissions worldwide, agreeing with the results of Lin et al. (2016), Boden et al. (2011), and Canadell et al. (2008).

With regard to energy intensity, the variable is a strong contributor to rising emissions as well under both specifications. For model I, the coefficient is 0.66 while for model II 0.20, indicating that a 1% increase in the energy intensity of the countries will lead to 0.66% (I) or 0.2% (II) increase in

Table 6 Results from panel long-run estimators

	Model I		Model II	
	OLS (FE)	FMOLS	OLS (FE)	FMOLS
GDP	3.32*	3.32*	–	–
GDP^2	− 0.11*	− 0.06*	–	–
IND	–	–	− 3.03*	−2.89*
IND^2	–	–	0.15*	0.11*
ES	0.97*	1.03*	0.74*	1.08*
EI	0.67*	0.66*	0.33*	0.20*
URB	− 0.54*	− 0.56*	0.71*	0.18*
POP	0.59*	0.62*	0.45*	0.43*
C	− 24.16*	–	13.13*	–
R^2	0.996	0.84	0.979	0.812
Hausman T.	1321.19*	–	411.27*	–

*denotes for 1% level of statistical significance emissions. A positive impact of intensity to gas emissions was also confirmed by Lin et al. (2016) and Shahbaz et al. (2015). A more efficient use of energy sources would be of assistance toward decreasing the level of emissions.

The level of urbanization is statistically significant in both models; however, the coefficient is negative when aggregate GDP is used, while the sign changes to positive when economic development is proxied by the industrial share. Other studies also conclude that the impact of urbanization changes depending on the kind of proxy for economic growth being used in the model (Lin et al. 2016; Sadorsky 2014; Martinez-Zarzoso 2008). The literature has not reached consensus on the sign of the impact of urbanization to energy consumption and emissions. Urbanization traditionally has a positive impact to emissions particularly at the initial stages of urbanization: population moves to urban areas to access employment opportunities, and hence improve their living conditions, income, and access to infrastructure and energy. Burton (2000), Capello and Camagni (2000), Poumanyvong and Kaneko (2010), Pachauri (2004), and Pachauri and Jiang (2008) confirm a negative relationship between urbanization and energy consumption and emissions. They base that on potential fuel substitution from inefficient fuels to more efficient forms of energy.

As expected, the coefficient for population growth denotes a positive impact to the rising levels of emissions (0.62 for model I and 0.43 for model II), ceteris paribus. Higher numbers of people lead to increasing needs for energy use in those countries; while at the same time, the demand for goods and services is also on the rise to cover for the extra individuals; and thus, the energy consumed to produce them also increases. All these increases in energy use lead to the increase in emissions, due to the supply mixes of these countries. An increase in population should also be complemented with an increase in the household income level and general economic conditions and living standards, to establish the channel to increase energy use and CO2 emissions (Gertler et al. 2013; Song et al. 2015).

Conclusion and policy implications

This paper's purpose is to evaluate the role of the economic structure of specific EU countries into testing the Environmental Kuznets Curve (EKC) hypothesis, in the form of the industrial sector's value added. Thus, this study aims at comparing and contrasting the results in the empirical relationship among economic development and environmental quality (measured in CO_2 emissions) using the frequently employed STRIPAT framework and panel cointegration and fully modified OLS (FMOLS) analysis.

This study reveals that the EKC hypothesis is not confirmed when industrial share is used as a proxy for economic structure even though the hypothesis is supported when economic growth is employed as an indicator. From a technical point of view for future research, replacing the proxy for affluence from GDP to the industrial sector's economic output cannot be used for robustness purposes. For the countries examined in this paper, higher levels of industrialization promote reductions in the emission levels, and not support the EKC hypothesis. The channel might be through access to modern, cleaner, more efficient technologies that promote environmentally friendly behaviors of the overall economy.

Overall, the living standards and purchasing power of the society are important with higher rates of economic growth, and people have more discretionary income after paying for basic necessities; therefore, they are more amenable to paying higher prices in return for better environmental standards. Initially, economic development leads to shifting from farming to manufacturing. This leads to greater environmental degradation. However, increased productivity and rising real incomes seen a third shift from industrial to the service sector. A developed economy has seen industrialization shrinks as a share of the economy. The service sector usually has a lower environmental impact than manufacturing.

Agreeing with Lin et al. (2016), studies that examine the relationship between environmental degradation and economic development through the EKC hypothesis should not omit the discussion around the conditions under which the hypothesis is confirmed. Our study is positioned in the literature among studies that disaggregate the sources and sectors of economic growth, complementary ones to those that examine various environmental indicators and pollutants. Further studies can work with a higher number of European countries once the data become available, and can employ ecological footprint in place of CO_2 emissions.

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