European Countries on a green path. Connections between environmental quality, renewable energy and economic growth

Abbruzzese, Matteo and Infante, Davide and Smirnova, Janna

Department of Economics Statistics and Finance - University of Calabria - Italy

12 May 2020

European Countries on a green path

Connections between environmental quality, renewable energy and economic growth

Matteo Abbruzzese, Davide Infante and Janna Smirnova

Department of Economics Statistics and Finance

University of Calabria, Campus di Arcavacata di Rende (Italy)

Version May 2020

Abstract

The paper investigates the environment-energy-growth relationship by exploring a panel data on 30 European economies for the period 1995-2015. We start by exploring traditional relation between environmental pollution expressed in green houses gases emissions as a whole (Kyoto Basket) as well as their three main components, carbon dioxide (CO_2), dioxide of methane (CH_4) and nitrous oxide (N_2O), and per capita income extending the model by considering the role of renewable energy sources (RES). Our results, based on both fixed effects and instrumental variable methodology, demonstrate that traditional U-shape environment-growth relationship that holds for European countries is strongly influenced by the presence of RES through the shift of the turning point to higher per capita income levels. Moreover, the estimates show that with the increase of per capita consumption based on RES, environmental pollution tends to decrease in different measures, in according to the specific pollutant. As argued in the economic literature, the increase in consumption from renewable sources may generate a substitution effect, which mostly influences nuclear energy rather than fossil fuels, leading to increasing the income level of the turning point. Our results show that this increase could be due to the endogenous nature of income and to omitted variables distortion, thus revealing the *true* turning point. This would suggest that the process of energy transition, through the diffusion of low-emission energy sources, should accelerate to produce significant impact on pollution reduction.

JEL classification: Q42; Q55; Q56; O33

Keywords: Environmental Kuznets Curve; economic growth; Kyoto basket; energy renewable sources; European countries.

1. Introduction

The aim of this paper is to investigate a recently emerged in the literature environment-energy-growth relationship by analysing the links between greenhouse gas emissions and its components, per capita income and renewable energy sources (RES) in order to explore the effective impact of RES on environmental renascence in European countries in recent years.

The present research is related to the recent branch of literature that focusing attention on the complex relationship existing between economic growth and environmental quality by taking into consideration recently available information on alternative sources of energy and some additional factors important in this regard. As known, economic research historically considered the relationship, known as Environmental Kuznets Curve (EKC), in different aspects. Recent studies added to the consolidated relationship between economic growth and pollution other factors, such as degree of urbanization (Hossain, 2011; Zhang and Zhao, 2014), economic openness (Atici, 2009; Kasman and Duman, 2015) and institutional aspects (Castiglione et al., 2012) among others. These studies, known as extended EKC, have confirmed the complexity of the relationship between income and emissions that calls for a new glance on the postulate that improving economic wellbeing implies environmental renaissance.

The most recent studies, advantaged by data availability, revaluate the links between growth and environment by introducing the impact of the renewable energy sources which, by one hand, permits to obtain more rigorous results but, by another hand, discover even more complex interconnections. This new field of research has been denominated as environment-energy-growth literature (Dogan and Seker, 2016; Adewuyi and Awoduni (2017).

The large-scale diffusion of renewable energy sources in the electricity, heating and transport sector has, in fact, generated an increasing interest in the literature which, with different methodological approaches, provides a qualitative and quantitative assessment of the renewable sources in the dynamics of economic growth and environmental quality. This environment-energy-growth literature (Dogan and Seker, 2016; Adewuyi and Awoduni (2017), owes its birth to the widespread awareness of environmental problems related to greater energy intensity (Van Ierland, 1993). In fact, Dogan and Seker (2016) testify the presence of environmental problems associated with a greater aggregate energy intensity. Many studies also confirm that the increase in total energy consumption corresponds to greater pollution (Atici, 2009; Zhang and Zhao, 2014; Kasman and Duman, 2015; Ozokcu and Ozdemir, 2017).

On the other hand, energy consumption from renewable sources is argued to have a positive effect on environmental quality (Lopez-Menendez et al., 2014; Bilgili et al., 2016; York and McGee, 2017).

This branch of literature has a certain degree of inhomogeneity among contributions. Besides diversity based on spatial or time elements and that based on investigative methodologies, the models differ for the functional forms used and for the presence of numerous additional control variables. In fact, some of the authors apply an extended EKC in quadratic form (Boluk and Mert, 2015; Bilgili et al., 2016; York and McGee, 2017) and/or cubic (Lopez-Menendez et al. 2014; Alvarez-Herranz et al., 2017). In these contributions, in addition to energy consumption from renewable sources, other factors are considered: the achievement of the European energy target (Lopez-Menendez et al., 2014), the degree of commercial openness (Sulaiman et al., 2013), the degree of urbanization (York and McGee, 2017), the consideration of public budget for research and development in the energy field (Alvarez-Herranz et al., 2017), energy efficiency (Liobikiene and Butkus, 2017), the rate of population growth (Zoundi, 2017) and total electricity production (York and McGee, 2017).

The closest for our research is that provided by Lopez-Menendez et al. (2014). The authors analyse the relationship between economic growth, greenhouse gas emissions and energy intensity derived from renewable sources. The dataset is based on a panel of twenty-seven European countries evaluated for the period 1996-2010. The estimated model is based on cubic function of the total greenhouse gas emissions. The authors argue that the inverted U-shaped trend of the curve occurs exclusively for countries with a high-energy intensity deriving from renewables since greater production of electricity from RES corresponds to a reduction in polluting emissions.

Also Bilgili et al. (2016) study the impact of energy consumption from renewable sources on per capita carbon dioxide emissions by estimating a quadratic EKC for seventeen OECD countries. The authors confirm the existence of the inverse U-shaped curve for some of the countries and demonstrate that with increasing consumption of renewable energy emissions reduce. Similar are Boluk and Mert (2015) results found for Turkey and Sulaiman et al. (2013) for Malasya.

Interesting are the results for twenty-five African countries provided by Zoundi (2017) who analyses the causal relationship between energy consumption from renewable sources, economic growth, population and carbon dioxide emissions for the period 1980-2012. The author estimates an extended EKC model, showing a negative impact on the environment associated with an increase in energy intensity and population growth. In the same time, it is shown that an increase in energy consumption from renewable sources generates a significant reduction in carbon dioxide emissions. The sample does not permit to identify the EKC, given that the countries analysed probably have not yet reached a level of income that leads to the decrease of pollution.

Important insights of environment-energy-growth literature are provided by York and McGee (2017) in their study on the impact of renewables on environmental quality. The authors argue that the effect of the production of electricity from renewable sources on emissions it is not constant, but varies according to the level of the GDP per capita. This result implies that in countries with high levels of GDP per capita, the increase in the production of electricity from renewable sources reduces polluting emissions less than in the countries with low level of income due to the fact that the production of electricity from renewable sources, instead of reducing the use of fossil fuels, tends to substitute the production of nuclear energy.

Furthermore, Alvarez-Herranz et al. (2017) and York and McGee (2017) show that in countries with high levels of energy produced from renewable sources, economic growth leads to the increase of the emissions to a greater extent than in the countries with low renewable energy consumption, confirming that the environmental effect of renewables is greater in low-income countries than in countries with medium-high incomes.

It can be noted that in environment-energy-growth studies, with the exception of Alvarez-Herranz et al. (2017) and Liobikiene and Butkus (2017), to evaluate the dampening effect of renewables, the authors focus on CO_2 emissions (Sulaiman et al., 2013; Lopez-Menendez et al., 2014, Boluk and Mert 2015; Bilgili et al ., 2016; York and McGee, 2017). However, given that the concept of greenhouse gas emissions includes a vast category of pollutants, and that the Kyoto Protocol (1997) that governs the so-called Kyoto basket refers to seven greenhouse gases (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sodium trifluoride and sulfur hexafloride), an analysis regarding a more complete Global Warming Potential scheme is required.

To our knowledge, with the exception of Lopez-Menendez et al. (2014), there is a lack of studies that evaluate the effect of energy consumption from renewable sources on the dynamics that link pollution to GDP in European countries. It seems important to evaluate energy consumption from renewable sources within European pollution-income relationship, characterized by a strong dependence on energy imports. As known, one of the important problems affecting the European energy sector is represented by the strong dependence on imports of primary energy sources. Moreover, the overall energy demand is satisfied mostly through the use of fossil fuels, present in small quantities on the European territory (Eurostat 2017b).

The analysis of the above studies suggests that estimating the dampening effect of renewables without taking into account the possible causal relationship between traditional energy sources and greenhouse gas emissions could generate distortions due to omitted variable bias, given that traditional energy sources represent an important predictor of polluting emissions (Boluk and Mert, 2014; Farhani and Shahbaz, 2014; Shafiei and Salim, 2014; Dogan and Sker, 2016).

In the light of these studies, our investigation contributes to environment-energy-growth literature by filling-in various lacunae by taking into account a panel of thirty European countries, assessed for the years 1995-2015, and estimating a multivariate model that analyses the relationship between various polluters of Kyoto Basket, economic growth and the consumption of energy coming from renewable, as well as traditional energy sources.

2. Econometric estimations

2.1. Model specification

In the context of the theoretical and analytical framework previously analysed, it would be interesting to empirically verify whether and to what extent the spread of renewable energy sources can represent an effective tool to reduce pollution in European countries. Transition to alternative sources of energy could, in fact, influence the relationship that links economic growth to environmental wellbeing. The primary objective of this work, therefore, is to analyse the environment-energy-growth relationship, in particular the links between consumption from renewable energy sources, income and greenhouse gas emissions. To this end a series of equations based on the following model should be estimated:

$$E_{it} = \alpha_i + \gamma_t + \beta_0 + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta_3 RES_{it} + Z_{it} + \varepsilon_{it} \quad (1)$$

The dependent variable E_{it} represents atmospheric pollution and is expressed by aggregated greenhouse gas emissions (GHG) or Kyoto Basket and by the greenhouses gases resulting mostly from production and consumption of firms and households, such as carbon dioxide (CO_2), methane dioxide (CH_4) and nitrous oxide (N_2O). Pollutants are measured in tons per inhabitant and are extracted from the Eurostat (2017) database.

The explanatory variables *Y* and Y^2 are pro capita GDP and squared pro capita GDP, measured in dollars and purchasing power parity (PPP) and coming from OECD (2017) database. The use of these variables refers to the basic EKC model and to environment-energy-growth model. Variable RES represents final energy consumption from primary renewable energy sources within the production processes, consumed by various categories of end users (families, public administration, services, transport, agriculture) and measured in per capita terajoules. In according to Bilgili et al. (2016), it is one of the best indicators to capture the effects of the diffusion of renewable energy sources. The validity of this variable is confirmed by EC/2009/28 directive that underlines that the share of renewable energy in gross final energy consumption is a key indicator for measuring the progress achieved by European Energy Strategy 2020 (2007).

The additional variable *Z* are considered to have an important impact on environmental quality. One is trade openness (*Trade*), expressed in the imports and exports as a share of GDP, suggested by Kasman e Duman (2015) and Dogan e Seker (2016), and another is population density (*PodDensity*), measured as amount of people per square kilometer of land surface. These two indicators, both extracted from extracted from the World Development Indicators (WDI) are found to have two-way effects on environmental quality (Castiglione et al., 2012; Atici, 2009).

Another additional variable is represented by the share of electricity generated from fossil fuels (*Fossil*), such as natural gas, oil and coal, compared to total production is expected, within the Environmental-Energy-Growth literature, to contribute in rising emissions. The validity of this variable, extracted from World Bank (2017) database, is confirmed by the literature (Adewuyi and Awodumi, 2017; Santana de Souza et al., 2018).

Finally, in the equation (1) α and γ represent the individual and temporal fixed effects respectively, while ε represents the error term. In order to evaluate elasticity effects, the variables are expressed in logarithmic terms. The panel consists of thirty European countries and covers the period of 1995-2015.

We, therefore, start by estimating a baseline model that has classical EKC specification and then estimate an environment-energy-growth model by introducing the effect of RES and additional variables Z. In particular, we evaluate the role of alternative energy sources by observing the elasticity of energy consumption from renewables with respect to the pollutant analysed. Furthermore, in accordance with Sulaiman et al. (2013) and York and McGee (2017), we counterbalance the role of renewable energy sources by taking into account other variables that are expected to influence the level of emissions. The definition of variables and the source of data used are reported in Table 1. The variables “Fertility” and “Labor Force” are used as instruments in 2SLS estimations in the robustness check section.

Table 1 – Variable definition and data sources

Variables	Definition	Source
GHG	Kyoto basket: tons of CO_2 equivalent per capita	Eurostat (2018b)
CO_2	Carbon dioxide: tons of CO_2 per capita	Eurostat (2018b)
CH_4	Methane dioxide: tons of CO_2 equivalent per capita	Eurostat (2018b)
N_2O	Nitrous oxide: tons of CO_2 equivalent per capita	Eurostat (2018b)
Y	GDP per capita in PPP	OECD (2017)
Res	Final consumption of renewable energy per capita in terajoule	Eurostat (2017d)
Trade	Share of imports and exports as a percentage to the GDP	WDI (2017)
PopDensity	Number of people per square kilometer of land area	WDI (2017)
Fossil	Share of electricity generated from fossil sources as ratio to the total	WDI (2017)
Fertility	Number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children in accordance with age-specific fertility rates of the specified year	WDI (2017)
LaborForce	Proportion of the population ages 15-64 that is economically active	WDI (2017)

2.2. Descriptive statistics

The descriptive statistics that explain in details the data used in the empirical analysis are reported in Table 2. In the period of observation, greenhouse gas emissions (GHG) do not undergo marked changes between the countries considered. For Kyoto basket and carbon dioxide emissions (CO_2) the role of eco-leaders belongs to North-Eastern Europe (Sweden, Lithuania, Latvia) and to Croatia, while countries with a high level of emissions are Luxembourg and Ireland. The most polluting countries are Luxemburg and Ireland. For methane dioxide emissions (CH_4) eco-leaders are Malta and Sweden, while for nitrous oxide emissions, South-Western European countries, including Malta and Portugal. On the other hand, the countries with high levels of dioxide (CH_4) and nitrous oxide emissions (N_2O) are represented by Ireland, Lithuania and the United Kingdom.

However, if the average per country level of emissions is considered, a decreasing trend in greenhouse gas emissions can be noted. In fact, Eurostat confirms that greenhouse gas emissions decreased by 22% compared to nineties (Eurostat 2018b).

As known, GDP per capita data for European countries represents major dispersion, with higher values for Luxembourg, Norway, Holland and Austria and lower for Romania, Bulgaria and Estonia. However, If we consider the whole sample, with the exception of the years of economic crisis, there is an increasing trend in GDP per capita with an average of $ 39,475.23 per inhabitant in 2015.

The consumption of energy from renewable sources is also heterogeneous in Europe. Renewable energy leaders are the countries of Northern Europe (Iceland, Norway, Finland and Sweden), the countries with low green energy consumption are Malta, UK, Slovakia and Ireland. By taking into consideration the average values, an increasing trend can be noted in the period under consideration. Other control variables such as population density (PopDensity) and trade openness (Trade) are those which undergo the important changes over time and space. As for the share of electricity generated from non-renewable sources (Fossil), the countries with high usage of fossil sources are Cyprus, Malta and Estonia, while those with low usage are Iceland, Sweden and Norway. The variables “Fertility” and “Labor force” are used as instruments in 2SLS estimations in the robustness check section.

Table 2 - Descriptive statistics

Variabile	Obs.	Mean	Std. Dev.	Min	Max
GHG	630	10.97112	4.190896	4.41151	30.74039
ln(GHG)	630	2.300449	0.344003	1.4738	3.3273
CO2	630	8.938578	3.863708	3.03281	28.74222
ln(CO2)	630	2.072581	0.38741	1.094424	3.253998
CH4	630	1.17697	0.527381	0.360308	4.185807
ln(CH4)	630	0.088947	0.370801	-1.020796	1.4317
N2O	630	0.663676	0.355824	0.105632	2.493873
ln(N2O)	630	-0.52882	0.487681	-2.247794	0.913837
GDP	630	27867	14760.92	5453.938	120553.9
ln(GDP)	630	10.09681	0.550316	8.604094	11.69985
[ln(GDP)]2	630	102.2479	10.95782	74.03043	136.8865
Res	630	0.006838	0.007174	0	0.041576
ln(Res)	623	-5.22358	1.073087	-10.58315	-3.18024
Trade	630	106.2285	58.57381	37.1079	410.1716
ln(Trade)	630	4.548805	0.463323	3.61383	6.016576
PopDensity	630	512.2185	1034.485	2.592019	5578.853
ln(PopDensity)	630	4.906191	1.629976	0.9524373	8.626739
Fossil	630	0.552408	0.306286	0.0001162	1
ln(Fossil)	630	-1.10224	1.674281	-9.060198	0

*Correlation matrixes of explanatory variables are provided upon request.

3. Results and discussion

Before proceeding with estimations of different specifications of equation 1, some diagnostic tests were performed to check for heteroskedasticity (Modified Wald test), autocorrelation (Wooldrige test) and cross-sectional dependence (Pesaran CD test). The diagnostic tests were applied for each pollutant for the fixed effects estimations, given that Hausman test provides empirical evidence in favour of the least squares estimation with dummy variables. The diagnostic tests demonstrate that the estimated models are characterized by the presence of heteroskedasticity, autocorrelation and cross-sectional dependence. Therefore, according to Boluk and Mert (2014), Ozokcu and Ozdemir (2017), the models have been re-estimated using Hoechle (2007) Driscoll-Kraay Standard Errors. In particular, in using the least squares estimator with dummy variables, this type of standard error (Liu et al., 2015) has been applied.

The results of the estimates are shown in Tables 3-5 where, each column reports a different specification, with the first specification reporting a traditional EKC model and other specification are obtained by adding additional explanatory variables and time dummies. The specification 6 corresponds to a complete version of the model describing environment-energy-growth relationship. First of all, it should be noted that the estimates demonstrate the presence of an EKC for all the pollutants under consideration, given that an inverted U-shape relationship between GDP and emissions is detected. In fact, the coefficients associated with per capita income and that associated with squared per capita income alternate positive and negative signs.

With regard to the role of renewable energy sources it can be noted that the environmental elasticity of these energy sources takes a negative sign in all the polluters under examination. The estimates show that with the increase of per capita consumption based on RES, environmental pollution tends to decrease in different measures, in according to a specific pollutant. This would suggest that the process of energy transition, through the diffusion of low-emission energy sources, should accelerate to produce significant impact on pollution reduction. As for additional control variables, in line with the Environment-Energy-Growth literature, the share of electricity generated from fossil fuels has a positive and statistically significant effect on total emissions of greenhouse gases (GHG), carbon dioxide (CO_2) and methane dioxide (CH_4). This effect is not recorded, however, for nitrous oxide (N_2O) emissions for which the share of electricity from fossil source is not statistically significant.

Table 3. Estimation results for Kyoto Basket (GHG)

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-8.371***	-6.067***	-7.530***	-5.627***	-3.288**	-0.242
	(2.710)	(1.787)	(2.386)	(1.577)	(1.606)	(1.602)
Y	2.283***	1.750***	1.977***	1.563***	1.386***	0.839***
	(0.567)	(0.349)	(0.498)	(0.301)	(0.293)	(0.236)
y^2	-0.121***	-0.091***	-0.103***	-0.080***	-0.073***	-0.044***
	(0.030)	(0.018)	(0.026)	(0.015)	(0.016)	(0.013)
RES	-	-	-0.071***	-0.056***	-0.063***	-0.051***
			(0.010)	(0.013)	(0.010)	(0.012)
Trade	-	-	-	-	0.038	0.052
					(0.027)	(0.048)
PopDensity	-	-	-	-	0.271**	0.365**
					(0.124)	(0.154)
Fossil	-	-	-	-	0.071***	0.053**
					(0.026)	(0.019)
Time dummies	-	Yes	-	Yes	-	Yes
Obs.	630	630	623	623	623	623
N. countries	30	30	30	30	30	30
Within R^2	0.2475	0.4337	0.3073	0.4696	0.3662	0.5142
Prob>F	0.0009	0.0009	0.0000	0.0000	0.0000	0.0000
	(9.03)	(18.88)	(30.44)	(882.41)	(41.51)	(605.72)
Pr fixed effects= 0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pr time effects= 0	-	0.0000	-	0.0000	-	0.0000
Turning point (per capita dollars)	12,505.00	14,993.68	14,721.83	17,478.90	13,268,53	13,823.02

Note: Driscoll-Kraay standard errors in brackets
*** significant at 1%; ** significant at 5%; * significant at 10%

Table 4. Estimation results for Carbon Bioxide (CO_2)

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-6.929**	-4.160*	-5.956*	-3.630*	-2.259	-1.985
	(3.339)	(2.199)	(2.942)	(1.935)	(1.720)	(1.727)
Y	1.934***	1.308***	1.581**	1.088***	1.067***	1.051***
	(0.701)	(0.427)	(0.613)	(0.366)	(0.359)	(0.334)
y^2	-0.103***	-0.069***	-0.082**	-0.056***	-0.056***	-0.055***
	(0.037)	(0.021)	(0.032)	(0.018)	(0.020)	(0.019)
RES		-	-0.081***	-0.064***	-0.071***	-0.072***
			(0.011)	(0.014)	(0.010)	(0.010)
Trade	-	-			0.038	0.051
					(0.031)	(0.036)
PopDensity	-	-	-	-	0.230**	0.255**
					(0.120)	(0.126)
Fossil	-	-	-	-	0.091***	0.091***
					(0.029)	(0.029)
Time dummies	-	Yes	-	Yes	-	Yes
Obs.	630	630	623	623	623	623
N. countries	30	30	30	30	30	30
Within R^2	0.1685	0.4035	0.2346	0.4064	0.3319	0.4707
Prob>F	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000
	(8.09)	(9.12)	(29.30)	(1958.73)	(56.39)	(481.28)
Pr fixed effects= 0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pr time effects= 0	-	0.0000	-	0.0000	-	0.0000
Turning point (per capita dollars)	11,948.36	13,072.43	15,371.09	16,552.38	13,772.41	14,108.67

Note: Driscoll-Kraay standard errors in brackets
*** significant at 1%; ** significant at 5%; * significant at 10%

Table 5. Estimation results for Methan Dioxide (CH_4)

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-14.010***	-12.958***	-12.899***	-12.312***	-7.015**	-7.617**
	(1.252)	(0.864)	(0.935)	(0.709)	(2.990)	(3.213)
Y	3.107***	2.805***	2.708***	2.525***	1.901***	1.900***
	(0.252)	(0.172)	(0.182)	(0.141)	(0.410)	(0.456)
y^2	-0.169***	-0.149***	-0.145***	-0.132***	-0.104***	-0.101***
	(0.013)	(0.009)	(0.009)	(0.008)	(0.022)	(0.024)
RES		-	-0.094***	-0.088***	-0.085***	-0.081***
			(0.010)	(0.011)	(0.011)	(0.013)
Trade	-	-			-0.015	-0.011
					(0.047)	(0.055)
PopDensity	-	-	-	-	0.369**	0.302**
					(0.154)	(0.152)
Fossil	-	-	-	-	0.037**	0.034**
					(0.015)	(0.014)
Time dummies	-	Yes	-	Yes	-	Yes
Obs.	630	630	623	623	623	623
N. countries	30	30	30	30	30	30
Within R^2	0.5155	0.5458	0.6009	0.6234	0.6212	0.6381
Prob>F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(314.07)	(116.71)	(204.03)	(1037.27)	(177.72)	(902.13)
Pr fixed effects= 0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pr time effects= 0	-	0.0000	-	0.0000	-	0.0000
Turning point (per capita dollars)	9,821.28	12,243.51	11,360.87	14,248.31	9,315.38	12,160.40

Note: Driscoll-Kraay standard errors in brackets
*** significant at 1%; ** significant at 5%; * significant at 10%

Table 6. Estimation results for Nitrous Oxide (N_2O)

Modelli 1-3	Dependent variable: ln(N_2O)					
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-24.323***	-22.401***	-23.279***	-21.838***	-8.551***	-8.954***
	(1.486)	(0.767)	(1.331)	(0.809)	(1.518)	(1.522)
Y	5.106***	4.545***	4.732***	4.320***	2.690***	2.540***
	(0.308)	(0.172)	(0.284)	(0.183)	(0.243)	(0.272)
y^2	-0.271***	-0.235***	-0.249***	-0.221***	-0.144***	-0.131***
	(0.016)	(0.011)	(0.015)	(0.011)	(0.013)	(0.015)
RES		-	-0.084***	-0.064***	-0.074***	-0.057***
			(0.011)	(0.014)	(0.011)	(0.012)
Trade	-	-			-0.010	-0.009
					(0.044)	(0.028)
PopDensity	-	-	-	-	-0.340***	-0.432***
					(0.114)	(0.081)
Fossil	-	-	-	-	0.005	0.013
					(0.022)	(0.022)
Time dummies	-	Yes	-	Yes	-	Yes
Obs.	630	630	623	623	623	623
N. countries	30	30	30	30	30	30
Within R^2	0.5044	0.5792	0.5297	0.5922	0.5583	0.6126
Prob>F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(154.25)	(330.28)	(174.56)	(2930.09)	(102.52)	(2843.68)
Pr fixed effects= 0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pr time effects= 0	-	0.0000	-	0.0000	-	0.0000
Turning point (per capita dollars)	12,340.77	15,838.71	13,386.56	17,566.61	11,387.57	16,230.64

Note: Driscoll-Kraay standard errors in brackets;
*** significant at 1%; ** significant at 5%; * significant at 10%

The variables of economic openness (Trade) and population density (PopDensity) show inhomogeneous results which vary according to the pollutant analysed. The coefficient associated with the variable Trade is not statistically significant for all the polluters. An increase in population density instead generates negative and statistically significant effect on environment: the related coefficient, with the exception of emissions of nitrous oxide, assumes a positive and statistically significant sign in all other specifications. This result is in line with the literature (Dutt, 2009; York and McGee, 2013; Alvarado et al., 2018) arguing that an increase in the population density implies degradation of environmental conditions.

As far as Kyoto basket (GHG) is concerned, the final consumption of renewable energy sources has a negative and statistically impact on this pollutant. A 1% increase in the final consumption of renewable energy sources corresponds to a reduction of pollution by a percentage that varies from 0.063% and 0.051%. The relationship between the degree of commercial openness and GHG is statistically weak given that when individual and temporal effects are controlled, the coefficient becomes statistically insignificant. Population density (PopDensity) and the share of electricity generated from fossil fuels (Fossil), on the other hand, have positive and statistically significant impact on GHG - an increase of 1% in the number of people per square kilometer corresponds to an increase in polluting emissions from 0.271% to 0.365% for different specifications. The share of electricity generated from fossil sources is also positive and statistically significant, ranging from 0.071% to 0.053%. Therefore, an increase in the share of electricity from coal, oil and gas implies an increase in total greenhouse gas emissions.

The estimations concerning carbon dioxide (CO_2) allow us to understand how carbon dioxide emissions play a dominant role in air pollution. In fact, the results for the Extended Kuznets curve model demonstrate that the final consumption of renewable energy sources have negative and statistically significant coefficients on this type of pollution. A 1% increase in final consumption from RES corresponds to a reduction of CO_2 emissions changing from 0.071% to 0.072%. The impact of commercial openness, is similar to that obtained for Kyoto basket, given that the coefficient associated is statistically insignificant. A certain degree of homogeneity is also found in the coefficients related to the population density and the share of electricity generated from fossil sources. Both coefficients have positive and statistically significant values. A 1% increase in the number of people per square kilometer corresponds to an increase in CO_2 emissions from 0.230% to 0.255%, while the share of electricity generated from fossil sources has an environmental elasticity of 0.091%.

The regression results for methane emissions (CH_4) demonstrate that the final consumption of renewable energy sources has a negative and statistically significant impact on this pollutant. The elasticity varies from 0.085% to 0.081% for the extended Kuznets Curve. Therefore, a 1% increase in final consumption of renewable sources generates a reduction in methane emissions for an average value of 0.08%. Contrasting are the results for economic openness – the coefficients associated with the Trade variable are negative and statistically insignificant. In the same time, in line with the results of the regressions for Kyoto basket (GHG) and for carbon dioxide (CO_2), the coefficients associated with population density and the share of electricity generated from fossil fuels are positive and statistically significant. In fact, a 1% increase in the Fossil variable is associated with a 0.034% increase in methane emissions. Similar increase in population density corresponds to an increase in CH_4 of 0.302%

The relationship between nitrous oxide (N_2O) and final consumption of renewable energy sources shows negative and statistically significant coefficients: a 1% increase in final consumption from RES corresponds to a reduction in per capita emissions of nitrous oxide from a minimum of 0.057% to a maximum of 0.084%. As in the case of methane dioxide emissions, also in this case the degree of economic openness assumes a no significant value. On the other hand, the coefficient of population density is a negative and statistically significant: a 1% increase in the population density corresponds to a reduction of emissions from 0.340% to 0.432%. Finally, contrary to our previous findings, the share of electricity generated from fossil fuels does not result significant. This result is probably due to the fact, unlike other polluters examined, this type of pollution is mostly related to the anthropogenic sources that is mostly connected to intensive agriculture, breeding and combustion of biomass.

As for the turning points, from our results it can be noted, that the level of income in the turning point changes when considering different specifications of the model. For traditional EKC specification, for Kyoto basket (GHG) the turning point varies from \$12.505 to \$14.994 dollars per capita considering and not for temporal effects, for CO_2 this range goes from \$11.948 to \$13.072, for CH_4 from \$9.821 to \$12.244 and for N_2O from \$12.341 to \$15.839.

Turning points are found to increase when we consider environment-energy-growth specifications. In fact, the range of change in the turning point for CO2 in this relationship goes from \$13.823 to \$17.479, for CO2 from \$13.772 to 16.552, for CH4 from 11.361 to 14.248 and for N2O from \$11.388 to 16.231. It can be seen that for all the pollutants the values are decisively higher with respect to traditional environment-growth relationship.

These results are in line with Mandal and Chakravarty (2018) who conduct a meta-analysis involving seventy-five different studies on EKC, with the purpose to evaluate the role played by energy variables in defining extended EKC turning points. Also Alvarez-Herranz et al. (2017) argue that the increase of income in the turning point is due to the presence of an interactive effect between the GDP per capita and the consumption from renewable sources that reflects the effect that income has on renewable sources in the correction of emission levels. In fact, the effect of income on emissions varies according to consumption from renewable sources and vice versa, while the environmental impact of renewables varies according to the level of income. In this way, according to Thombs (2017), renewable energy sources have paradoxical effects on pollution since, in an energy transition phase, the reduction of emissions requires a greater increase in per capita income.

In the literature there have been many explanations for the increase of turning points. York and McGee (2017) and Alvarez-Herranz et al. (2017) argue that the increase in consumption from renewable sources generates a substitution effect which, in the initial stages, mostly influences nuclear energy rather than fossil fuels. Whilst our results suggest that the increase in the turning point could be due to the endogenous nature of income and to omitted variables distortion, thus revealing the *true* turning point. This hypothesis justifies the application of the two-stage least squares method in order to provide estimations in a consistent manner also to identify the *true* turning point.

4. Robustness check

In order to avoid problems related to the endogenous nature of GDP per capita with respect to pollution and take into consideration possible reverse causality or distortion due to omitted variables, we follow the methodology implemented by Lin and Liscow (2013), Alvarez-Herranz et al. (2017) and Liobikiene and Butkus (2017) applying instrumental variables estimations.

In this field of literature he contributions that apply the method of instrumental variables are limited. Possible tools to correct the endogenous nature income is age dependency ratio (Lin and Liscow, 2013), inflation rate (Balsalobre Lorente and Alvarez-Herranz, 2016) or the urbanization rate (Alvarez-Herranz et al., 2017). We propose to use as an instrument a fertility rate, defined as "the number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children in accordance with age-specific fertility rates of the specified year" and labour force, defined as "the proportion of the population ages 15-64 that is economically active", both taken from World Development Indicators (2018).

Both instruments are reasonably valid as they are highly correlated with the GDP per capita and have no direct effect on environmental quality except through their influence on income. Both variables are also taken in quadratic form, following the approach of other authors (Lin and Liscow, 2013; Balsalobre-Lorente and Alvarez-Herranz, 2016; Alvarez-Herranz et al., 2017).

An instrumental variables regression model that takes into consideration environment-energy-growth specification by considering fixed and time effects and covers the period from 1995- 2015 for 31 countries, is the following:

$$ln\,(y)_{it} = \alpha_i + \pi_0 + \pi_1\, ln\,(RES)_{it} + \pi_2 ln\,(TRADE)_{it} + \pi_3 ln\,(PopDensity)_{it} + \pi_4\, ln(Fossil)_{it} + \pi_5\, ln(Fertility)_{it} + \pi_6[ln\,(Fertility)]^2_{it} + \pi_7\, ln(LaborForce)_{it} + \pi_8[ln\,(LaborForce)]^2_{it} + V_{1it} \quad \textbf{(2)}$$

$$[\ln\,(y)]^2_{it} = \alpha_i + \pi_0 + \pi_1\, \ln(RES)_{it} + \pi_2 \ln(TRADE)_{it} + \pi_3 ln\,(PopDensity)_{it} + \pi_4\, ln(Fossil)_{it} + \pi_5\, ln(Fertility)_{it} + \pi_6[\ln\,(Fertility)]^2_{it} + \pi_7\, ln(LaborForce)_{it} + \pi_8[\ln\,(LaborForce)]^2_{it} + V_{2it} \quad \textbf{(3)}$$

Where additional to previous variables are "*Fertility*", staying for fertility rate and "*LaborForce*", staying for the share of active population; V_1 and V_2 are the error terms.

The instruments, in linear and in quadratic form, are tested for the correlation the endogenous variables, by applying F-test showing that both instrumental variables significantly affect the GDP per capita. The exogeneity of the instruments, given that the model is over-specified, is controlled by overidentifying restrictions test (Baum, 2006), performed in the two versions proposed by Sargan (1958) and Basmann (1960). The results of the test, available upon request, confirm that the instruments adopted are exogenous with respect to the greenhouse gas emissions analyzed.

Finally, the application of Durbin-Wu-Hausman endogeneity test indicates the need to use the instrumental variables estimations to overcome the problem of the endogeneity of the GDP in all the environmental indicators under consideration. Tables 7 and 8 show the results of the second stage estimates. To avoid problems of consistency, standard errors robust to heteroskedasticity and autocorrelation (clustered standard errors) are used.

The results of the estimations with instrumental variables confirm the hypothesis of an inverted U-shaped relationship between emissions and per capita income. The turning point values vary according to the pollutant analyzed. In considering temporal effects, the turning point for GHG is 33.558.74; for CO_2 is 31.451.99, for CH_4 is 16,705.92 and for N_2O is

22,362.74, while without considering temporal effects, the turning point for GHG is 20.571.35; for CO_2 is 15,343.48, for CH_4 is 15,343.48 and for N_2O is 15,872.19.

Instrumental variables methodology confirms our previous findings. The increase in income counteracts greenhouse gas emissions and the consumption from renewable energy sources has an important role in reducing air pollution. In fact, the second stage demonstrates a negative and statistically significant coefficient of the RES variables for all the pollutants. The coefficient of environmental elasticity of energy consumption from renewable sources is negative and statistically significant for all the pollutants, in particular for GHG it amounts to 0.101% (without temporal effects) and 0.099% (with temporal effects); for CO_2 0.115% (without time effects) and 0.108% (with time effects); for CH_4 0.098% (without time effects) and 0.106% (with time effects;) for N_2O to 0.091% (without time effects) and 0.085% (with time effects).

The results for the additional control variables (Trade, PopDensity and Fossil) do not vary significantly compared to the previous estimations. A certain degree of homogeneity is observed, in fact, for the share of electricity generated from fossil sources and for the population density: the coefficients associated with these two variables are positive and statistically significant for GHG, CO_2 and CH_4 while for N_2O they are not statistically significant. The degree of economic openness (Trade) is positively related with all the polluters under examination.

Table 7 - *Two Stage Least Square (2SLS)*: results for Kyoto Basket (GHG) and Carbon Dioxide (CO2)

	Dependent variable: *ln(GHG)*	Dependent variable: *ln(GHG)*	Dependent variable: *ln(C_2O)*	Dependent variable: *ln(C_2O)*
Variables	(1)	(2)	(3)	(4)
Constant	-25.091***	-26.889***	-18.996**	-18.623**
	(6.307)	(7.016)	(7.370)	(8.100)
ln(y)	5.522***	5.544***	4.254***	3.815**
	(1.206)	(1.431)	(1.325)	(1.547)
$[\ln(y)]^2$	-0.278***	-0.266***	-0.211***	-0.173**
	(0.061)	(0.074)	(0.067)	(0.080)
ln(Res)	-0.101***	-0.099***	-0.115***	-0.108***
	(0.018)	(0.024)	(0.019)	(0.025)
ln(Trade)	-0.079	-0.150	-0.143	-0.117
	(0.079)	(0.110)	(0.087)	(0.122)
ln(PopDensity)	0.406**	0.484**	0.404**	0.468**
	(0.174)	(0.199)	(0.194)	(0.198)
ln(Fossil)	0.073***	0.049**	0.084***	0.051**
	(0.019)	(0.022)	(0.021)	(0.024)
Fixed effects	Yes	Yes	Yes	Yes
Time effects	-	Yes	-	Yes
Obs.	613	613	613	613
N. countries	30	30	30	30
R^2	0.9251	0.9075	0.9300	0.9169
Adj R^2	0.9205	0.8985	0.9257	0.9088
Prob>F	0.0000 (286.38)	0.0000 (107.24)	0.0000 (221.91)	0.0000 (142.93)
Pr Fixed effects= 0	Pr= 0.0000	Pr= 0.0000	Pr= 0.0000	Pr= 0.0000
Pr Time effects= 0	-	Pr= 0.0000	-	Pr= 0.0000
Turning point (per capita dollars)	20,571.35	33,558.74	23,874.55	31,451.99

Note: *Robust standard errors* in brackets.
*** significant at 1%; ** significant at 5%; * significant at 10%

Table 8 - *Two Stage Least Square (2SLS):* Results for methane dioxide (CH4) and nitrous oxide (N2O)

	Dependent variable: $ln(CH_4)$	Dependent variable: $ln(CH_4)$	Dependent variable: $ln(N_2O)$	Dependent variable: $ln(N_2O)$
Variables	(1)	(2)	(3)	(4)
Constant	-47.874***	-54.357***	-35.887***	-36.623***
	(8.074)	(7.824)	(8.312)	(8.716)
ln(y)	9.677***	10.832***	7.409***	7.271***
	(1.541)	(1.472)	(1.599)	(1.678)
$[\ln(y)]^2$	-0.502***	-0.557***	-0.383***	-0.363***
	(0.078)	(0.074)	(0.082)	(0.087)
ln(Res)	-0.098***	-0.106***	-0.091***	-0.085***
	(0.022)	(0.022)	(0.018)	(0.020)
ln(Trade)	0.127	0.140	-0.025	-0.095
	(0.088)	(0.098)	(0.089)	(0.104)
ln(PopDensity)	0.768***	0.891***	-0.225	-0.462
	(0.223)	(0.283)	(0.481)	(0.529)
ln(Fossil)	0.080***	0.093***	0.008	0.002
	(0.017)	(0.021)	(0.019)	(0.023)
Fixed effects	Yes	Yes	Yes	Yes
Time effects	-	Yes	-	Yes
Obs.	613	613	613	613
N. countries	30	30	30	30
R^2	0.9154	0.9094	0.9399	0.9422
Adj R^2	0.9103	0.9006	0.9362	0.9366
Prob>F	0.0000 (296.33)	0.0000 (165.44)	0.0000 (629.64)	0.0000 (425.68)
Pr Fixed effects= 0	Pr= 0.0000	Pr= 0.0000	Pr= 0.0000	Pr= 0.0000
Pr Time effects= 0	-	Pr= 0.0000	-	Pr= 0.0000
Turning point (per capita dollars)	15,343.48	16,705.92	15,872.19	22,362.74

Note: *Robust standard errors* in brackets.
*** significant at 1%; ** significant at 5%; * significant at 10%

5. Concluding remarks

As recent literature demonstrates, an important role in the dynamics of environmental sustainability in different countries is played by the environment-energy-growth relationship. It is suggested that the increase in greenhouse gas emissions is an energy-related phenomenon that is mainly derived from the widespread use of fossil fuels for the production of energy. This field of research is, however, characterized by some critical aspects, such as the lack of attention for other than carbon dioxide emissions (CO_2), high methodological divergence, the lack of consideration of the endogenous nature of income. Our investigation aims to fill-in these gaps, by focusing attention on the relationship between pollution, economic growth and RES and verify whether an increase in the use of renewable energy implies a reduction in polluting emissions and contributes to obtain a better pollution-income path.

Based on a panel data of thirty-one European countries, for a period from 1995 to 2015, we estimate a multivariate model that takes into consideration four different indicators of air pollution: Kyoto basket (GHG), carbon dioxide (CO_2), dioxide of methane (CH_4) and nitrous oxide (N_2O). The results of the estimations confirms the existence of the inverted U-shape relationship between pollution and income in both, traditional EKC specification and environment-energy-growth relationship: an increase in the GDP per capita leads to an increase in emissions at the initial stage and, subsequently, to the reduction of environmental pollution. A common feature for all the polluters concerns the role played by renewable energy sources in environment-energy-growth relationship. The results confirm that applying renewable energy resources leads to environmental renascence.

Our research adds to the literature, first of all, the analysis of a new set of environmental pollution indicators and explanatory variables taken into consideration. In fact, the analysis covers GHG as a whole and as its single components, while the set of explanatory variables contains a certain degree of novelty with respect to existing research regarding the consideration of some important factors that influence pollution, such as renewable and traditional energy sources, economic openness and population density.

From the methodological point of view, we apply the Hoechle (2007) Driscoll-Kraay standard errors to avoid the problems of heteroskedasticity, autocorrelation and longitudinal dependence in panel data. Moreover, to address the problem of endogeneity of per capita income 2SLS estimation was applied to obtain income-pollution elasticity which is rarely done within the literature of the field. In this context, the novelty concerns the choice of instrumental variables such as fertility rate and labour force, chosen on the basis of the test of over-identification restrictions to check for exogeneity and the relevance of the variables applied.

An important result concerns turning point identification for all types of the pollution analysed. We find that in comparing the basic EKC model to environment-energy-growth relationship, the level of income in turning points gets substantially higher. There have been various explanations for this forward variation in the turning points. York and McGee (2017) and Alvarez-Herranz et al. (2017) are led to believe that the increase in consumption from renewable sources generates a substitution effect which, in the initial stages, mostly influences nuclear energy use rather than fossil fuels.

Our results lead us to believe that the increase in the turning point is due to the endogenous nature of the GDP per capita and to distortion problems from omitted variables. This strongly justifies the application of the two-stage least squares method in order to estimate the income-pollution relationship in an undistorted and consistent manner, thus revealing a higher *true* turning point.

The hypothesis contained in the environmental model of Kuznets suggests that, in order to quickly reach the turning point of the curve, policy-makers should carry out interventions aimed at promoting ever faster GDP growth rates. In reality, as also supported in the seminal article by Panayotou (1993), a policy that dedicates most of its resources to growth is not necessarily optimal because, even if environmental degradation is physically reversible, the turning point in the report growth-pollution could occur in a point (the *shadow area* according to Borghesi, 1999) which would make environmental pollution an irreversible problem. For these reasons, the optimal strategies for an effective reduction of greenhouse gas emissions should be those oriented to firmly support the policy of incentivizing the production of energy from renewables coupled with a policy aimed at stimulating sustainable growth based mainly on a de fossilization (gas, oil and coal) of the production processes.

References

Adewuyi A. O., Awodumi O. A. (2017). Renewable and non-renewable energy-growth-emission linkages: Review of emerging trends with policy implications. *Renewable and Sustainable energy Reviews*, 69, 275–291.

Alvarado R., Ponce P., Criollo A., Cordova K., Khan M. K. (2018). Environmental degradation and real per capita output: New evidence at the global level grouping countries by income levels. *Journal of Clean Production,* 189, 13-20.

Alvarez-Herranz A., Balsalobre-Lorente D. (2015). Energy Regulation in the EKC model with a Dampening effect," *Environmental Analytical Chemistry*, 2(3), 4-10.

Alvarez-Herranz A., Balsalobre-Lorente D., Shahbaz M., Cantos J. M. (2017). Energy innovation and renewable energy consumption in the correction of air pollution levels. *Energy policy,* Vol. 105, 386-397.

Atici C. (2009) "Carbon emissions in Central and Eastern Europe: environmental Kuznets curve and implication for sustainable development. *Sustainable Development*, 17(3), 155-160.

Balsalobre-Lorente D., Álvarez-Herranz A. (2016). Economic growth and energy regulation in the environmental Kuznets curve," *Environmental Science and Pollution Research*, 23(16), 16478–16494.

Balsalobre-Lorente D., Alvarez-Herranz A. (2017). An approach to the effect of Energy Innovation on Environmental Kuznets Curve: An introduction to Inflection Point. *Bulletin of Energy Economics*, 4(3), 225-233.

Basmann R. L. (1960). On finite sample distributions on generalized classical linear identifiability test statistics. *Journal of the American Statistical Association*. (55), 650–659.

Baum C. F. (2006), *An introduction to modern econometrics using stata*, Stata Press, Texas.

Bilgili F., Kocak E., Bulut U. (2016). The dynamic impact of renewable energy consumption on CO_2 emissions: A revisited Environmental Kuznets Curve approach. *Renewable and Sustainable Energy Reviews*, 54, 838-845.

Boluk G., Mert M. (2014). Fossil & renewable energy consumption, GHGs (greenhouse gases) and economic growth: Evidence from a panel of EU (European Union) countries. *Energy,* 74(1), 439-446.

Borghesi S. (1999). The Environmental Kuznets Curve: a Survey of the Literature. FEEM Working Paper N. 85.

Castiglione C., Infante D., Smirnova J. (2012). Rule of law and the environmental Kuznets curve: evidence for carbon emissions. *International Journal of Sustainable Economy*, 4(3), 254-269.

Dogan E., Seker F. (2016). Determinants of CO_2 emissions in the European Union: The role of renewable and non-renewable energy. *Renewable Energy*, 94, 429-439.

Dogan E., Seker F. (2016). The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. *Renewable and Sustainable Energy Reviews*, 60, 1074-1085.

Dutt K. (2009). Governance, institutions and the environment-income relationship: a cross-country study. *Environment, Development and Sustainability*, 11(4), 705-723.

European Commission (2007), *European Energy Strategy 2020*, Brussels.

European Environment Agency (EEA), (2016), *Manual for the EEA greenhouse gas data viewer,* 1-11.

European Environment Agency (EEA), (2016), *Manual for the EEA greenhouse gas data viewer*, 1-11.

European Environment Agency (EEA), (2016), A*ir pollutant emission inventory guidebook*, 1-28.

Eurostat, (2017a), *Climate change – driving forces*, 1-30.

Eurostat, (2017b), *Energy production and imports*, 1-11.

Eurostat, (2017c), *National accounts and GDP*, 1-23.

Eurostat, (2017d), *Renewable energy statistics*, 1-10.

Eurostat, (2018a), *Air pollution statistics- emission inventories*, 1-30.

Eurostat, (2018b), *Greenhouse gas emission statistics- emission inventories*, 1-6.

Farhani S., Shahbaz M. (2014). What role of renewable and non-renewable electricity consumption and output is needed to initially mitigate CO_2 emissions in MENA region?. *Renewable and Sustainable Energy Review*, 40, 80–90.

Hoechle D. (2007). Robust standard errors for panel regressions with cross-sectional dependence», *Stata Journa*l, 7(3), 281-312.

Hossain M. S. (2011). Panel estimation for CO_2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. *Energy Policy,* 39(11), 6991-6999.

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

Lin, C.-Y. C., Liscow, Z. D. (2013). Endogeneity in the Environmental Kuznets Curve: An Instrumental Variables Approach. *American Journal of Agricultural Economics*, 95(2), 268-274.

Liobikiene G., Butkus M. (2017). Environmental Kuznets Curve of greenhouse gas emissions including technological progress and substitution effects. *Energy*, 135, 237-248.

Lopez-Menendez A. J., Perez R., Moreno B. (2014). Environmental costs and renewable energy: Re-visiting the Environmental Kuznets Curve. *Journal of Environmental Management*, 145, 368-373.

Mandal S. K., Chakravarty D. (2018). Role of Energy in estimating turning point of Environmental Kuznets Curve: an econometric analysis of the existing studies. *Journal of Social and Economic Development*, 19, (2), 387-401.

Ozokcu S., Ozdemir O. (2017). Economic growth, energy, and environmental Kuznets curve. *Renewable and Sustainable Energy Reviews*, 72, 639-647.

Panayotou T. (1993). Empirical Tests and Policy Analysis of The Environmental Degradation at Different Stages of Economic Development. WP, World Development Programmed Research: Technology and Employment Programmed, 1-45.

Pesaran M. H. (2004). General Diagnostic Tests for Cross Section Dependence in Panels. University of Cambridge, 1-41.

Santana de Souza E., Freire F. D. S., Pires J. (2018). Determinants of CO_2 emissions in the MERCOSURE: the role of economic growth, and renewable and non-renewable energy. *Environment Science and Pollution Research*, 25(21), 20769-20781.

Sargan, J. D. (1958). The Estimation of Economic Relationships using Instrumental Variables. *Econometrica*, 26(3), 393-415.

Shafiei S., Salim R. A. (2014). Non-renewable and renewable energy consumption and CO_2 emissions in OECD countries: A comparative analysis. *Energy Policy*, 66, 547-556.

Sulaiman J., Azman A., Saboori B. (2013). The potential of renewable Energy: using the environmental Kuznets curve model. *American Journal of Environment Science*, 9(2), 103-112.

Thombs R. P. (2017). The paradoxical relationship between renewable energy and economic growth: a cross-national panel study, 1990-2013. *Journal of World-Systems Research*, 23(2), 540-564.

Van Ierland E. C. (1993), *Macroeconomic analysis of environmental policy,* Elsevier Science Publishers BV, Amsterdam.

York R., McGee J. A. (2017). Does Renewable Energy Development Decouple Economic Growth from CO_2 Emissions?. *Sociological Research for a Dynamic World*, 3, 1-6.

Zhang C., Zhao W. (2014). Panel estimation for income inequality and CO_2 emissions: A regional analysis in China. *Applied Energy*, 136, 382-392.

Zoundi Z. (2017). CO_2 emissions, renewable energy and the Environmental Kuznets Curve, a panel cointegration approach. *Renewable and Sustainable Energy Reviews*, 72, 1067-1075.