The Environmental Kuznets Curve: The Role of Renewable and Non-Renewable Energy Consumption and Trade Openness

Mehdi Ben Jebli and Slim Ben Youssef and Ilhan Ozturk

Manouba University, University of Jendouba, Cag University

November 2013

The Environmental Kuznets Curve: The Role of Renewable and Non-Renewable Energy Consumption and Trade Openness

Mehdi Ben Jebli
LAREQUAD & FSEGT, University of Tunis El Manar, Tunisia
University of Jendouba, ISI du Kef, Tunisia.
Email: benjebli.mehdi@gmail.com

Slim Ben Youssef
Manouba University, ESC de Tunis, LAREQUAD, Tunisia.
Email : slim.benyoussef@gnet.tn

Ilhan Ozturk
Faculty of Economics and Administrative Sciences,
Cag University, 33800, Mersin, Turkey.
Email: ilhanozturk@cag.edu.tr
Tel & Fax: +90 324 6514828

November, 2013

Abstract: We use panel cointegration techniques to investigate the causal relationship between CO_2 emissions, renewable and non-renewable energy consumption, and trade openness in three different models for a panel of twenty five OECD countries over the period 1980-2009. Also the validity of the Environmental Kuznets Curve (EKC) hypothesis has been tested for these countries. Short-run Granger causality tests show the existence of a unidirectional causality running from the square of per capita output to per capita CO_2 emissions and per capita non-renewable energy consumption and a unidirectional causality running from per capita real exports to per capita CO_2 emissions. There is an indirect short-run causality running from per capita output to per capita non-renewable energy consumption. In the long-run, the FMOLS and DOLS estimates suggest that per capita GDP and per capita non-renewable energy consumption have a positive impact on per capita CO_2 emissions. The long-run estimates suggest that the square of per capita GDP, per capita renewable energy consumption, and per capita real exports and imports have a negative impact on per capita CO_2 emissions. Therefore, more trade openness and more use of renewable energy are efficient strategies to combat global warming.

Keywords: Environmental Kuznets curve; Renewable energy; Non-renewable energy; Trade openness; CO_2 emissions; Panel cointegration techniques.
JEL Classifications: C33; F14; Q42; Q43; Q54

1. Introduction

This paper tries to capture the impact of economic growth, renewable energy consumption, non-renewable energy consumption and international trade on CO_2 emissions. This study is interesting because, to our knowledge, there is no previous empirical research that has studied the impact of renewable energy consumption and international trade on CO_2 emissions.

For many decades, the demand of fossil fuel energy attends an exponential growth rate which caused disaster and catastrophic damages on the environment. The emissions of greenhouses gases such carbon dioxide (CO_2) are very dangerous aspects that may be considered as the main cause of global warming. However, the consumption of non-renewable energy (oil, coal, natural gas) does not only increase the economic growth but also increases the emissions of CO_2. Thus, it is necessary to find a substitutable energy to the fossil one such renewable energy.

Recent econometric studies have explored the relationship between economic growth and the consumption of renewable energy (e.g. Apergis and Payne, 2010a, 2010b, 2011, 2012; Sadorsky, 2009; Tugcu et *al*., 2012). The direction of causality between these variables is varied and the long-run association reveals the significant impact of renewable energy on emissions without impairing effects of deteriorating economic growth. On the dynamic of the long-run causality relationship, Apergis and Payne (2011, 2012) suggest that the error correction term confirm the existence of bidirectional causality between renewable energy consumption and economic growth. Additionally, the substitutability between renewable and non-renewable energy consumption have been established in Apergis and Payne (2012) for both the short and the long-run. These findings may derive governments and policy makers to reduce the use of non-renewable energy and enable the enlargement of the renewable energy sector. Using a classical augmented production functions, Tugcu et al., (2012) make a comparison between renewable and non-renewable energy sources in order to decide which type of energy is more important for economic growth in the G7 countries. The authors conclude that bidirectional feedback hypothesis between renewable and non-renewable energy and economic growth has been supported. According to these results, we can agree on the vital role of renewable energy in the progresses of the GDP.

Before discussing the purpose of this present paper, let's start with some previous studies. In fact, there are several empirical studies that debate the causal links between economic growth and environmental quality. However, the results recommended from these papers are not consensus on the direction of causality between these variables. These preceding econometric studies declared that four possibilities discussing the direction of causality between pollution-economic growth nexus for the case of bivariate framework are estimated (unidirectional causality from GDP to emissions, from emissions to GDP, bidirectional causality, or no causal links between them). The majority of these studies may alter the causal direction between variables. Based on the environmental Kuznets curve (EKC) hypothesis, the direction of causality between these variables has been used within a trivariate framework by incorporating the square of real GDP, or a multivariate framework by also incorporating energy or trade.

With respect to the EKC hypothesis, we think that there is no empirical study discussing the causality relationship between environmental indicator controls (CO_2 emissions), renewable and non-renewable energy consumption, and economic growth in the case of time series and/or panel estimation. To our knowledge, all previous empirical studies incorporate the total energy consumption in the specific model for the analysis. However, our present models consider that energy consumption is divided between renewable and non-renewable energy. Several econometric studies that investigate the causal relationship between environmental indicators and per capita real income or per capita real GDP related to the hypothesis of Kuznets. At the beginning, the empirical studies associated to the EKC literature revolves around the quadratic and cubic relationship between emissions and real GDP (e.g. Cole, 2005; De Bruyn, 1998; Fosten et *al*. 2012; Galeotti et *al*., 2006; Jaunky, 2011; Narayan and Narayan, 2010; Shen and Hashimoto, 2004) for cross-section and panel of countries.

Recently, the econometric studies related to the theory of EKC have been advanced by incorporating other deterministic factors to the environmental indicator such as energy consumption and trade openness for the case of individual country (e.g. Ang, 2007; Suri and Chapman, 1998; Halicioglu, 2009; Jalil and Mahmud, 2009 Ozturk and Acaravci, 2010; Jayanthakumaran et *al*., 2012; Shahbaz et al., 2013) and for the case of panel (e.g. Acaravci and Ozturk, 2010; Arouri et *al*., 2012; Haggar, 2012; Ozcan, 2013).

Other than the EKC literature review, there are some empirical analysis that investigate the causal links between renewable energy consumption and economic growth in log-linear models (e.g. Apergis and Payne, 2010a, 2010b, 2011, 2012; Sadorsky, 2009) or between emissions, economic growth and renewable energy consumption (e.g. Apergis and Payne, 2009; Apergis et *al*., 2010) using panel cointegration techniques and more powerful methods of estimation such as fully modified ordinary least squares (FMOLS) or dynamic ordinary least squares (DOLS).

The present paper tries to investigate the causal nexus between CO_2 emissions, economic growth, renewable and non-renewable energy consumption and trade openness. Using the EKC specification, we aim to use panel cointegration techniques for a sample of countries belonging to the Organization for Economic Co-operation and Development (OECD) in three different specification models including different variants of the trade variable. The first model debates the causal links between per capita CO_2 emissions, per capita real GDP, square of per capita real GDP and per capita renewable energy consumption. In the second model we incorporate non-renewable energy consumption in order to check for its impact on emissions. The third model incorporates both renewable and non-renewable energy consumption and trade openness, either per capita real exports or per capita real imports, in order to examine the separated effect of each trade variable on emissions. Since there is no study which investigates the causal nexus between CO_2 emissions, economic growth, renewable and non-renewable energy consumption and trade openness for OECD countries, this paper aims to fulfill this gap and contribute to the empirical literature.

The rest of the paper is organized as follows: Section 2 presents literature review; Section 3 provides data information, modeling and methodology; Section 4 gives empirical results and Section 5 deals with conclusion and policy implications.

2. Literature Review

It is worth important to review some empirical studies that examine the EKC hypothesis. But given that there is no previous literature related to the Kuznets hypothesis and exploring the relationship between emissions, economic growth, renewable and non-renewable energy consumption and trade openness, then, the literature review presented in this section is limited to the existing literature which is concentrated on the causality between emissions, economic growth, energy consumption, and/or trade. There are a large and growing number of studies investigating the causal links between CO_2 emissions, real income, energy consumption and/or international trade associated with the Kuznets hypothesis. Two strands have been presented below and examine the causal links between these variables.

The first strand is related to the cross-sectional studies (e.g. Ang, 2007; Halicioglu, 2009; Jalil and Mahmud, 2009; Ozturk and Acaravci, 2010; Jayanthakumaran et *al*., 2012; Shahbaz et al., 2013). Ang (2007) studies the validity of EKC hypothesis for the case of France by using cointegration and vector error-correction modeling techniques. The results provide the existence of a robust long-run relationship. The long-run association support that economic growth exerts a causal influence on growth of energy consumption and growth of pollution. In the short-run, the results provide that there is a unidirectional causality running from growth of energy consumption to economic growth. By incorporating the trade variable, Halicioglu (2009) examines the causal relationship between carbon emissions, energy consumption, income, and trade in the case of Turkey by using the ARDL bounds testing to cointegration procedure. The results from the bounds indicate that there are two forms of long-run equilibrium. The first form is that carbon emissions are explained by energy consumption, income and trade, and the second form is that carbon emissions, energy consumption, and trade are determinants of income. From the first form which respects the EKC hypothesis, the empirical results suggest that income is the most significant variables followed by energy consumption and trade. Jalil and Mahmud (2009) examined the long-run relationship between carbon emissions and energy consumption, income and foreign trade in the case of China by employing time series data of 1975–2005. Auto regressive distributed lag (ARDL) methodology is employed for empirical analysis. A quadratic relationship between income and CO_2 emission has been found for the sample period, supporting EKC relationship. The results of Granger causality tests indicate one way causality runs through economic growth to CO_2 emissions. The results of this study also indicate that the carbon emissions are mainly determined by income and energy consumption in the long run. Trade has a positive but statistically insignificant impact on CO_2 emissions. Ozturk and Acaravci (2010) examined the long run and causal relationship issues between economic growth, carbon emissions, energy consumption and employment ratio in Turkey by using autoregressive distributed lag bounds testing approach of cointegration for the period 1968–2005. The estimated income elasticity of carbon emissions per capita is −0.606 and the income elasticity of energy consumption per capita is 1.375. Results for the existence and direction of Granger causality show that neither carbon emissions per capita nor energy consumption per capita cause real GDP per capita, but employment ratio causes real GDP per capita in the short run. In addition, EKC hypothesis at causal framework by using a linear logarithmic model is not confirmed in Turkish. Jaunky (2011) tests the Environment Kuznets Curve (EKC) hypothesis for 36 high-income countries for the period 1980–2005 using various panel data unit root and co-integration. Unidirectional causality running from real per capita GDP to per capita CO_2 emissions is uncovered in both the short-run and the long-run. The empirical analysis based on individual countries provides evidence of an EKC for Greece, Malta, Oman, Portugal and the United Kingdom. However, it can be observed that for the whole panel, a 1% increase in GDP generates an increase of 0.68% in CO_2 emissions in the short-run and 0.22% in the long-run. The lower long-run income elasticity does not provide evidence of an EKC, but does indicate that, over time, CO_2 emissions are stabilising in the rich countries. Jayanthakumaran et *al*. (2012) This paper compares China and India using the bounds testing approach to cointegration and the ARDL methodology to test the long- and short-run relationships between growth, trade, energy use and endogenously determined structural breaks for 1971-2007 period. The CO_2 emissions in China were influenced by per capita income, structural changes and energy consumption. A similar causal connection cannot be established for India. Shahbaz et al. (2013) investigate between CO_2 emissions, energy intensity, economic growth and globalization using annual data over the period of 1970–2010 for Turkish economy by using applied unit root test and cointegration approach in the presence of structural breaks. The empirical evidence reported that energy intensity and economic growth (globalization) increase (condense) CO_2 emissions. The results also validated the presence of environmental Kuznets curve (EKC). The causality analysis shows bidirectional causality between economic growth and CO_2 emissions.

The second strand consists on studies examining the causal links between emissions, energy consumption and/or trade for panel countries (Acaravci and Ozturk, 2010; Arouri et *al*., 2012; Haggar, 2012; Jaunky, 2011; Ozcan, 2013). Acaravci and Ozturk (2010) investigated the causal relationship between carbon dioxide emissions, energy consumption, and economic growth by using autoregressive distributed lag (ARDL) bounds testing approach of cointegration for nineteen European countries for 1960-2005 period. They found a positive long-run elasticity estimate of emissions with respect to energy consumption at 1% significant level in Denmark, Germany, Greece, Italy and Portugal. Positive long-run elasticity estimates of carbon emissions with respect to real GDP and the negative long-run elasticity estimates of carbon emissions with respect to the square of per capita real GDP at 1% significance level in Denmark and 5% significant level in Italy are also found. These results support the validity of environmental Kuznets curve (EKC) hypothesis only in Denmark and Italy. The long-run causal relationship between greenhouse gas emissions, energy consumption and economic growth have been investigated by Haggar (2012) for a panel of Canadian industrial sectors. The findings of the short-run conveys that there is one a way causality running from energy consumption and economic growth to greenhouse gas emissions; a weak unidirectional causality from greenhouse gas emissions to energy consumption. The long-run findings reveal that energy consumption has a positive and significant impact on emissions and the inverted U-shaped of the EKC hypothesis has been supported. Arouri et *al*. (2012) employed recent bootstrap panel unit root tests and cointegration techniques to examine the relationship between carbon dioxide emissions, energy consumption, and real GDP for 12 Middle East and North African Countries (MENA) over the period 1981–2005. Their results show that in the long-run energy consumption has a positive significant impact on CO_2 emissions. Also real GDP exhibits a quadratic relationship with CO_2 emissions for the region as a whole. However, although the estimated long-run coefficients of income and its square satisfy the EKC hypothesis in most studied countries, the turning points are very low in some cases and very high in other cases, hence providing poor evidence in support of the EKC hypothesis. CO_2 emission reductions per capita have been achieved in the MENA region, even while the region exhibited economic growth over the period 1981–2005. Ozcan (2013) discusses the empirical nexus between carbon emissions, energy consumption and economic growth in the Middle East countries. The results suggest that the U-shaped EKC is not favorable for five countries but has been identified for three countries, whereas there are no causal links between emissions and income for the remaining sample countries.

3. Data, Specification Models and Methodology

3.1. Data

Data on renewable and non-renewable energy are per capita and in billion kilowatt hours, CO_2 emissions per capita in metric tons, real GDP per capita in constant 2005 US dollars, real exports in US dollars and real imports in US dollars during the period of 1980-2009 for a panel of twenty five OECD countries[1]. The database is selected to get the maximum number of observations depending on the availability of the data and time period. Data on renewable energy is measured as geothermal, solar, wind, tide and wave, biomass and waste, and hydro electric power consumption. The non-renewable energy consumption is coming from the sum of electricity consumption from oil, gas, and coal. Renewable and non-renewable energy data are obtained from the U.S. Energy Information Administration (EIA) online database. These data are obtained in billion kilowatt hours and we divide them by the population number to get the per capita unit. Data on per capita CO_2 emissions, real GDP per capita, merchandise exports and merchandise imports are obtained from the World Bank Development Indicators online database (WDI, 2013). The annual data on merchandise exports (imports) are transformed from the current value to the real one by dividing them by the consumer price index (pc) and then they are divided by population to get the per capita unit. Data on the consumer price index and population are obtained from the Penn World Tables version 7.1 (Heston et *al*. 2012). All variables are transformed to the natural logarithms form. Our estimations are done using Eviews 7.0 software.

[1] Australia, Austria, Belgium, Canada, Chile, Denmark, Finland, France, Greece, Hungary, Iceland, Italy, Japan, South Korea, Mexico, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.

3.2. Specification models

The specification models of the present paper follow the methodology developed by Ang (2007), Halicioglu (2009) and Jayanthakumaran et *al*. (2012) for time series and by Haggar (2012) and Narayan and Narayan (2010) for heterogeneous panel. Based on the environmental Kuznets curve hypothesis, the multivariate framework is established to investigate the long-run relationship between per capita carbon dioxide (*e*), per capita real GDP (*y*), squared of per capita real GDP (y^2), per capita renewable energy consumption (*re*), per capita non-renewable energy consumption (*nre*) and trade openness (*ex* or *im*) for panel dependence. With respect to the EKC hypothesis, we advance three separate panels to examine the estimated causality of the short and long-run links where emission of CO_2 is the dependent variable. The first model discusses on the causal association between emissions, per capita real GDP, square of per capita real GDP, and per capita renewable energy consumption. In the second model, we keep the same previous specification but we replace the renewable energy consumption by the non-renewable energy consumption (*nre*) as an independent variable to examine its effect on the emissions growth. In order to examine the individual effect of trade openness, whether exports or imports, the third model is divided into two sub-models: the first sub-model includes per capita real exports (*ex*) and the second one includes per capita real imports (*im*). The log linear quadratic forms corresponding to each model are specified as follows:

<u>*Panel A*</u>: $$e_{it} = \alpha_{0i} + \kappa_i t + \alpha_{1i} y_{it} + \alpha_{2i} y_{it}^2 + \alpha_{3i} re_{it} + \varepsilon_{it} \quad (1)$$

<u>*Panel B*</u>: $$e_{it} = \beta_{0i} + \sigma_i t + \beta_{1i} y_{it} + \beta_{2i} y_{it}^2 + \beta_{3i} nre_{it} + \mu_{it} \quad (2)$$

<u>*Panel C:*</u> $$e_{it} = \delta_{0i} + \rho_i t + \delta_{1i} y_{it} + \delta_{2i} y_{it}^2 + \delta_{3i} re_{it} + \delta_{4i} nre_{it} + \delta_{5i} o_{it} + \pi_{it} \quad (3)$$

where $i = 1,...,25$ and $t = 1980,...,2009$ indicate the country and time series, respectively. $(\alpha_{0i}, \beta_{0i}, \delta_{0i})$ and $(\kappa_i, \sigma_i, \rho_i)$ denote the country specific fixed effects and deterministic trends corresponding to each panel, respectively. $(\varepsilon_{it}, \mu_{it}, \pi_{it})$ indicate the estimated residuals which characterize deviations from the long-run equilibrium. The trade variable is referred by (*o*), whether per capita real exports or per capita real imports. The parameters $\langle (\alpha_{1i}, \alpha_{2i}, \alpha_{3i}); (\beta_{1i}, \beta_{2i}, \beta_{3i}); (\delta_{1i}, \delta_{2i}, \delta_{3i}, \delta_{4i}, \delta_{5i}) \rangle$ are the long-run elasticities corresponding to each explanatory variable of the panels *A*, *B* and *C*, respectively. With respect to the EKC hypothesis, the sign of $(\alpha_{1i}, \beta_{1i}, \delta_{1i})$ vector is expected to be positive, whereas the sign of $(\alpha_{2i}, \beta_{2i}, \delta_{2i})$ vector is expected to be negative. According to the EKC hypothesis, an increase in real GDP would lead to an increase in emissions, whereas an increase in the square of real GDP would lead to a decrease in emissions. The sign corresponding to the vector $\langle \alpha_{3i}, \beta_{3i}, (\delta_{3i}, \delta_{4i}) \rangle$ is expected to be mixed and depending on the specific economic development of the selected panel. We expect that with renewable energy, the sign is negative if the level of energy used is high enough and the industrial sectors use the clean technology for production; but it could be positive if the level of renewable energy is rather low and the technology used for production is polluting. With non-renewable energy consumption, the sign is expected to be positive. The sign of δ_{5i} is expected to be mixed and also depends on the economic development of the selected countries. Most of the studies exploring the relationship between CO_2 emissions, economic growth, energy use, and international trade (e.g. Grossman and Krueger, 1995; Halicioglu, 2009; Shahbaz et *al*., 2012) reveal that the sign of trade openness slope parameter is positive if the dirty industries of developing economies are producing with heavy share of CO_2 emissions.

3.3. Methodology

The short and long-run dynamic causality between emissions, output, renewable and non-renewable energy, and trade openness is the aim purposed by this paper. We use panel cointegration techniques to investigate the relationship among variables for a panel of twenty five OECD countries during the period 1980-2009. Our empirical analysis consists in the following stages: *i)* analysis of some descriptive statistics, *ii)* examination of the stationary proprieties using traditional panel unit root tests, *iii)* testing the existence of long-run relationship among variables using Pedroni cointegration tests, *iv)* whether variables are cointegrated and the possibility of long-run association is established, we run the Granger causality tests to check for the direction of causality, *v)* estimation of the long-run coefficients corresponding to each panel by using the FMOLS and DOLS techniques, and *vi)* concludes.

4. Empirical Analysis

Table 1 presents some descriptive statistics of the selected variables over the period 1980-2009. The summary common statistics contain the means, median, maximum and minimum of each series after transformation in logarithms form.

Table 1. Descriptive statistics of the variables

	emissions	*real GDP*	*renewable energy*	*non-renewable energy*	*exports*	*imports*
Mean	8.513513	26365.08	54.43648	1826.23	53743.54	54579.03
Median	7.766421	26474.64	23.68950	491.78	39433.79	42078.59
Maximum	20.77751	67804.55	433.6361	25266.06	347073.0	343003.2
Minimum	1.725601	2898.221	0.020000	49.27	882.4837	2398.779

Notes: emissions of CO2 are measured in per capita metric tons, per capita real GDP are measured in US dollars constant 2005, renewable and non-renewable energy consumption in billion kilowatt hours, per capita real exports and imports of merchandise are measured in US dollars.

According to these statistic results, the highest level of per capita CO_2 emissions was in the Unites States (20.78 metric tons per capita in 1980) while the lowest level was in Turkey (1.73 metric tons per capita in 1980). The real GDP per capita was highest in Norway (67804.55 US dollars constant 2005 in 2007) and the lowest level was in Chile (2898.221 US dollars constant 2005 in 1983). The Unites States was the biggest consumer of renewable energy (433.64 billion kilowatt hours in 1997) and non-renewable energy (25266.06 billion kilowatt hours in 2007), and the smallest consumers of renewable energy and non-renewable energy are Netherlands (0.02 billion kilowatt hours in 1984) and Iceland (49.27 billion kilowatt hours in 1995), respectively. Regarding to the maximum level of per capita real exports and per capita real imports, Belgium is the richest country with 347073.0 US dollars (2008) and 343003.2 US dollars (2008), respectively, whereas Turkey is the poorest country with 882.4837 US dollars (1980) and 2398.779 US dollars (1980), respectively.

Table 2. Panel unit root tests

Variables	e	Δe	y	Δy	y^2	Δy^2
Method/statistics	Level	First diff.	Level	First diff.	Level	First diff.
Null: Unit root (assumes common unit root process)						
Levin, Lin & Chu t	2.188	-18.535***	4.432	-1.631*	-5.364	-1.483*
Breitung t-stat	0.524	-4.730***	-	-	-	-
Null: Unit root (assumes individual unit root process)						
Im, Pesaran and Shin W-stat	-0.127	-18.589***	2.627	-5.239***	0.781	-6.803***
ADF - Fisher Chi-square	70.051**	372.904***	40.847	115.951***	35.568	148.114***
PP - Fisher Chi-square	78.887***	1317.93***	19.108	93.546***	33.205	126.910***

Variables	*re*	*Δre*	*nre*	*Δnre*	*ex*	*Δex*
Method/statistics	Level	First diff.	Level	First diff.	Level	First diff.
Null: Unit root (assumes common unit root process)						
Levin, Lin & Chu t	-1.328	-23.668***	-0.934	-13.060***	-1.748	-4.440***
Breitung t-stat	-0.592	-16.409***	3.605	-2.608***	-	-
Null: Unit root (assumes individual unit root process)						
Im, Pesaran and Shin W-stat	0.461	-25.442***	-1.052	-15.340***	1.946	-13.507***
ADF - Fisher Chi-square	68.451**	523.703***	82.918***	344.175***	29.962	267.320***
PP - Fisher Chi-square	77.166***	599.918***	76.753***	415.660***	53.081	278.238***

Variables	*im*	*Δim*
Method/statistics	Level	First diff.
Null: Unit root (assumes common unit root process)		
Levin, Lin & Chu t	-3.180***	-9.086***
Breitung t-stat	-	-
Null: Unit root (assumes individual unit root process)		
Im, Pesaran and Shin W-stat	3.590	-14.836***
ADF - Fisher Chi-square	14.758	292.792***
PP - Fisher Chi-square	22.205	255.470***

Notes: ***, **, and * indicate statistical significance at the 1% , 5%, and 10% levels, respectively. All variables are tested with intercept and trend except for real GDP, the square of real GDP, real exports and real imports. Automatically lag length selection based on the Schwarz Information Criterion (SIC).

In this empirical study we used five different unit root tests to check for the integration order of each variable. Breitung (2000), Levin et *al*. (2002), Im et *al*. (2003), tests of Fisher use Augmented Dickey and Fuller (ADF) (1979), and Phillips and Perron (1988). These tests are composed on two groups: the first group of tests includes t-statistic of the Breitung (2000) and LLC's test (Levin et *al*., 2002). These tests assume a common unit root process across the cross-section for the null of a unit root. The second group of tests includes IPS-W-statistic (Im et *al*., 2003); ADF-Fisher Chi-square (Dickey Fuller, 1979) and PP-Fisher Chi-square (Phillips and Perron, 1988). These tests assume an individual unit root process across the cross-section. For all these tests, the null hypothesis is that there is a unit root and the alternative hypothesis is that there is no unit root. Panel unit root is tested using intercept and deterministic trend for CO_2 emissions, renewable and non-renewable energy consumption variables, and for all the other variables we use only intercept and no trend.

The results of the panel unit root tests are presented in Table 2. All unit root statistics reported in the table are tested at level and after first difference for the selected variables. The result from these integration tests indicate that, for the per capita emissions of CO_2 three tests among five cannot reject the null hypothesis of non-stationary at level while after taking the first difference, the five tests reject the null of non-stationary at the 1% level of significance. The real GDP per capita and the square of real GDP per capita are both non-stationary at the level form and become stationary after the first difference. LLC's, Breitung t-stat and IPS-W statistics confirm that renewable and non-renewable energy consumption per capita have a unit root at level, whereas after the first difference all tests suggest that the null hypothesis of non-stationary can be rejected at the 1% significance level. For the per capita real exports and per capita real imports, the null hypothesis of no unit root cannot be rejected at level for all individual unit root tests except the LLC statistics which is statistically significant at 1% level for imports, whereas after first difference they become stationary at the 1% significance level. Finally, it is evident to conclude that all variables have a unit root and are stationary after first integration.

Table 3. Pedroni cointegratin tests

Alternative hypothesis: common AR coefs. (within-dimension)				
	Panel A		***Panel B***	
	Statistic	Weighted Statistic	Statistic	Weighted Statistic
Panel v-Statistic	1.356442*	1.429507*	1.749838**	0.472653
Panel rho-Statistic	-2.145296**	-2.672105***	-3.017385***	-3.406204***
Panel PP-Statistic	-5.220214***	-5.822650***	-6.297343***	-7.880556***
Panel ADF-Statistic	-4.418057***	-4.829175***	-5.253308***	-7.761142***
Alternative hypothesis: individual AR coefs. (between-dimension)				
	Statistic		Statistic	
Group rho-Statistic	-0.971503		-1.532338*	
Group PP-Statistic	-5.471601***		-9.276788***	
Group ADF-Statistic	-4.705912***		-7.780121***	
Alternative hypothesis: common AR coefs. (within-dimension)				
	Panel C1		***Panel C2***	
	Statistic	Weighted Statistic	Statistic	Weighted Statistic
Panel v-Statistic	0.153297	-0.239044	1.541748	1.124342
Panel rho-Statistic	-0.092991	-1.117970	-0.599100	-0.796557
Panel PP-Statistic	-3.865140***	-6.116198***	-4.881188***	-5.330418***
Panel ADF-Statistic	-3.017363***	-4.960240***	-4.589187***	-5.323954***
Alternative hypothesis: individual AR coefs. (between-dimension)				
	Statistic		Statistic	
Group rho-Statistic	1.174407		0.918346	
Group PP-Statistic	-4.857765***		-5.306893***	
Group ADF-Statistic	-3.373015***		-5.257045***	

Notes: *,**, and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively. Panel A, B, C1, and C2 refer to panel with renewable energy; panel with non-renewable energy; panel with renewable and non-renewable energy and exports; and panel with renewable and non-renewable energy and imports, respectively. The null hypothesis is that there is no cointegration among variables whereas alternative hypothesis is that there is cointegration. Lag length selection based on SIC (automatically) with a max lag of 6 for panels A and B and a max lag of 5 for panels C1 and C2.

The existence of long-run dynamic relationship between variables should be tested for each selected panel. To do that, we use Pedroni (1999, 2004)'s panel cointegration tests to check for long-run association among variables. Pedroni (1999, 2004) purposes two sets of cointegrartion tests. The first is a panel group based on four statistics and includes v-statistic, rho-statistic, PP-statistic and ADF-statistic. These statistics are classified on the within-dimension and take into account common autoregressive coefficients across countries. The second group is based on three statistics and includes rho-statistic, PP-statistic, and ADF statistic. These tests are classified on the between-dimension and based on the individual autoregressive coefficients for each country in the panel. All these tests are based on the residuals of Eqs. (1-3). For all these tests, the null hypothesis is that there is no cointegration whereas the alternative hypothesis is that there is cointegration between variables. Compared to other cointegration techniques such as Kao (1999)'s homogeneous cointegration tests, the advantage of Pedroni tests is that they take into account the heterogeneity across countries.

The results from Pedroni cointegration tests are reported in Table 3. For the first panel (panel A) cointegration tests, all the within dimension tests and two of the between dimensions tests (group PP-statistic and group ADF-statistic) confirm the rejection of the null hypothesis of no long-run association between variables. Thus, six tests among seven suggest that there is a cointegration between emissions, economic growth and renewable energy consumption.

For the panel B, all the within and the between dimension tests confirm the rejection of the null hypothesis of no cointegration. Therefore, there is a long-run association between CO_2 emissions, economic growth and non-renewable energy consumption.

For the panels C1 and C2, the results from these tests confirm that the null hypothesis of no cointegration can be rejected at the 1% significance level because two tests of the within dimension (panel PP-statistic and panel ADF-statistic) and two tests of the between dimension (group PP-statistic and group ADF-statistic) approve this rejection. Thus, four tests among seven reveal that the variables move together in the long-run equilibrium. The non-weighted statistics of the within dimension for panels conserve approximately the same significance as the weighted statistics. In conclusion, the seven tests of the Pedroni's cointegration techniques confirm the existence of long-run links between the analysis variables for each panel and the direction of causality must be examined.

After establishing the existence of long-run linkages between CO_2 emissions, real GDP, square of real GDP, renewable and non-renewable energy consumption and trade factors, we will examine the direction of causality between them. Engle and Granger (1987) recommend a two-steps procedure for cointegration analysis. The first step is to estimate the long-run equilibrium from Eqs. (1-3) through FMOLS technique to recover the residuals considered as a lagged error correction term (*ect*). The second step is to estimate the dynamic error correction model corresponding to each panel.

$$\Delta e_{it} = \lambda_{0i} + \sum_{j=1}^{p} \lambda_{1ij} \Delta e_{it-j} + \sum_{j=1}^{p} \lambda_{2ij} \Delta y_{it-j} + \sum_{j=1}^{p} \lambda_{3ij} \Delta y_{it-j}^{2} + \sum_{j=1}^{p} \lambda_{4ij} \Delta re_{it-j} + \alpha_i ect_{it-1} + \eta_{it} \tag{4}$$

$$\Delta e_{it} = \phi_{0i} + \sum_{j=1}^{p} \phi_{1ij} \Delta e_{it-j} + \sum_{j=1}^{p} \phi_{2ij} \Delta y_{it-j} + \sum_{j=1}^{p} \phi_{3ij} \Delta y_{it-j}^{2} + \sum_{j=1}^{p} \phi_{4ij} \Delta nre_{it-j} + \beta_i ect_{it-1} + \zeta_{it} \tag{5}$$

$$\Delta e_{it} = \gamma_{0i} + \sum_{j=1}^{p} \gamma_{1ij} \Delta e_{it-j} + \sum_{j=1}^{p} \gamma_{2ij} \Delta y_{it-j} + \sum_{j=1}^{p} \gamma_{3ij} \Delta y_{it-j}^{2} + \sum_{j=1}^{p} \gamma_{4ij} \Delta re_{it-j} + \sum_{j=1}^{p} \gamma_{5ij} \Delta nre_{it-j}$$
$$\sum_{j=1}^{p} \gamma_{5ij} \Delta o_{it-j} + \theta_i ect_{it-1} + \psi_{it} \tag{6}$$

where Δ indicates the first difference, p denotes the lag length determined automatically by the Schwarz Information Criterion (SIC). The lagged error term (ect) is generated from Eqs.

(4-6), and ($\alpha_i, \beta_i, \theta_i$) are the speed of adjustment coefficients. (*o*) refer to the trade variable whether real exports per capita or real imports per capita. The Granger causality tests are employed to investigate the long-run relationship with the negative sign of the lagged *ect* and its statistical significance using t-statistic and the short-run relationship is investigated by lagged differences of variables specified in each equation using F-statistic.

Table 4. Pairwise Granger causality tests

Null Hypothesis:	F-Statistic	Prob.
y does not Granger Cause e	2.22767	0.1085
e does not Granger Cause y	0.57229	0.5645
y2 does not Granger Cause e	2.45842	0.0863*
e does not Granger Cause y2	0.66971	0.5122
re does not Granger Cause e	1.22187	0.2953
e does not Granger Cause re	1.35267	0.2592
nre does not Granger Cause e	0.08248	0.9208
e does not Granger Cause nre	0.00676	0.9933
ex does not Granger Cause e	2.79379	0.0618*
e does not Granger Cause ex	1.67782	0.1875
im does not Granger Cause e	1.55223	0.2125
e does not Granger Cause im	1.70967	0.1816
y2 does not Granger Cause y	7.70496	0.0005***
y does not Granger Cause y2	7.87643	0.0004***
re does not Granger Cause y	0.02504	0.9753
y does not Granger Cause re	1.17682	0.3088
nre does not Granger Cause y	0.51154	0.5998
y does not Granger Cause tr	2.07650	0.1261
ex does not Granger Cause y	1.68419	0.1863
y does not Granger Cause ex	0.34975	0.7050
im does not Granger Cause y	2.09195	0.1242
y does not Granger Cause im	1.55794	0.2113
re does not Granger Cause y2	0.01030	0.9898
y2 does not Granger Cause re	1.19068	0.3046
nre does not Granger Cause y2	0.63020	0.5328
y2 does not Granger Cause nre	2.45079	0.0869*
ex does not Granger Cause y2	1.51024	0.2215
y2 does not Granger Cause ex	0.24683	0.7813
im does not Granger Cause y2	1.94755	0.1434
y2 does not Granger Cause im	1.29248	0.2752
nre does not Granger Cause re	1.41010	0.2448
re does not Granger Cause nre	1.29060	0.2757
ex does not Granger Cause re	1.33918	0.2627
re does not Granger Cause ex	0.53911	0.5835
im does not Granger Cause re	1.47803	0.2288
re does not Granger Cause im	1.06769	0.3443
ex does not Granger Cause nre	2.07184	0.1267
nre does not Granger Cause ex	1.28313	0.2778
im does not Granger Cause nre	1.91257	0.1484

nre does not Granger cause im	1.97999	0.1388

Notes: ****, **, * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Null hypothesis: No causality. The number of lags is equal to two.

To check for the direction of the short-run causality between variables, we run the pairwise Granger causality tests. These tests are used to survey the way of short-run causality between variables in pairs. The number of lags selected for the tests is equal to 2 and determined automatically with respect to the Schwarz Information Criteria (SIC). The Granger causality tests are examined for the direct and the indirect short-run mechanism. The results from theses short-term tests are reported in Table 4. The short-run causality tests suggest that there is no evidence of direct causality between emissions and economic growth, whereas there is only one way causality running from the square of real GDP to the CO_2 emissions without feedback at the 10% significance level. There is also a unidirectional causality running from the square of real GDP per capita to the non-renewable energy consumption per capita statistically significant at 10% level. Short-run causality tests suggest for the panel C1 that real exports Granger cause emissions at the 10% significance level. It means that there is a one way directional causality from exports to emissions and any increase in merchandise exports will deviate the environmental control.

There is some evidence of an indirect causal relationship between economic growth and emissions which runs from real GDP to CO_2 emissions because real GDP Granger causes the square of real GDP and this latter Granger cause CO_2 emissions. The evidence of no short-run causality between emissions and renewable energy consumption and the existence of a short-run causality from economic growth to emissions are the results of our empirical Granger analysis. These findings are not exactly similar to those of Apergis et *al*. (2010) for a panel of 19 developed and developing countries. These authors show that renewable energy consumption and economic growth both have a positive and statistically significant contribution on emissions in the short-term. They also show that renewable energy consumption does not contribute in the decrease of emissions as nuclear energy. The results in Apergis et *al.* (2010) are similar to the findings of Menyah and Wolde-Rufael (2010) for US. There are certainly some clarifications that justify the causes of non-contribution of renewable energies on the emissions. The first reason is, in comparison to the non-renewable energy, renewable energy level is not sufficiently high and has not sufficiently increased which slows its influence on emissions and economic growth. The second reason is related to a higher increase in the consumption of oil and natural gas which make renewable energy less attractive. Another reason is relatively related to the selected sample and the analysis time period. The findings of no short-run causality between renewable energy consumption and economic growth is not similar to the results of Apergis and Payne (2010a) for a panel of 20 OECD countries and also not similar to the Apergis et *al*. (2010)'s findings. We think that this divergence is due to the differences in the selected time period and in the collected variables used in the case of log linear quadratic EKC estimated models.

Table 5. VECM for the long-run direction causality

Panel equation	*ECT*	
Eq. (4) *Panel A: e, y, y2, re*	-0.000936	[-2.70952]***
Eq. (5) *Panel B: e, y, y2, nre,*	-0.005188	[-2.61685]**
Eq. (6a) *Panel C1: e, y, y2, re, nre, ex*	-0.007014	[-2.88366]***
Eq. (6b) *Panel C2: e, y, y2, re, nre, im*	-0.007350	[-2.44383]**

Notes: ***and ** denote statistical significance at the 1% and 5% levels, respectively. The t-statistic is listed in brackets.

The direction of the long-run causality has been tested through the significance of the error correction term corresponding to each estimated panel (Table 5). With respect to Eq. (4) (panel A), the error correction term is negative and statistically significant at the 1% level. It means that there is a long-run association that runs from per capita real GDP, square of per capita real GDP and the consumption of renewable energy per capita to the per capita CO_2 emissions. With respect to Eq. (5) (panel B), the error correction term is also negative and statistically significant at the 5% level. However, analysis variables move together in the long-run and runs from all independent variables to emissions. With respect to Eq. (6) (panels C1 and C2), the error correction terms are both negative and statistically significant at the 1% and 5% levels for the model with exports and imports, respectively. This result affirms that there is a long-run relationship that runs from per capita real GDP, square of per capita real GDP, renewable and non-renewable energy consumption per capita and per capita real exports (per capita real imports) to per capita CO_2 emissions.

Given the existence of a long-run association between variables for each specification model, the next step consists to estimate the long-run coefficients using FMOLS and DOLS estimators. The FMOLS approach estimation has been proposed by Pedroni (2001, 2004) whereas the DOLS approach has been recommended by Kao and Chiang (2001), and Mark and Sul (2003) for the panel case. These two approaches are more powerful than OLS. However, the advantage of FMOLS non-parametric technique is that it corrects for both endogeneity bias and serial correlation. DOLS is a parametric technique adjustment of the errors by augmenting the static regression with lags and contemporaneous values of the regressors in first differences (Ouedraogo, 2013).

Table 6. FMOLS-DOLS long-run estimates

Panel A		FMOLS			DOLS	
Variable	Coefficient	t-Statistic	Prob.	Coefficient	t-Statistic	Prob.
y	5.172379	4.914500	0.0000***	5.089614	4.704480	0.0000***
y2	-0.238130	-4.398277	0.0000***	-0.233368	-4.185772	0.0001***
re	-0.061732	-3.349753	0.0004***	-0.059447	-3.202850	0.0008***
Panel B		FMOLS			DOLS	
Variable	Coefficient	t-Statistic	Prob.	Coefficient	t-Statistic	Prob.
y	5.229222	4.750466	0.0000***	5.000947	4.521669	0.0000***
y2	-0.255941	-4.207574	0.0000***	-0.243772	-3.978453	0.0000***
nre	0.297054	-3.703737	0.0000***	0.302358	-3.610083	0.0000***
Panel C1		FMOLS			DOLS	
Variable	Coefficient	t-Statistic	Prob.	Coefficient	t-Statistic	Prob.
y	3.680914	4.471563	0.0002***	3.658727	3.684434	0.0000***
y2	-0.165619	-3.821954	0.0012***	-0.165409	-3.204395	0.0014***
re	-0.069040	-3.907874	0.0000***	-0.065892	-4.278573	0.0000***
nre	0.310875	6.221719	0.0000***	0.309032	6.116406	0.0000***
ex	-0.117011	-3.075216	0.0022***	-0.094550	-2.462992	0.0140**
Panel C2		FMOLS			DOLS	
Variable	Coefficient	t-Statistic	Prob.	Coefficient	t-Statistic	Prob.
y	4.054833	4.218798	0.0000***	3.903969	4.023384	0.0001***
y2	-0.184422	-3.706751	0.0002***	-0.177179	-3.527252	0.0004***
re	-0.072141	-4.788425	0.0000***	-0.069010	-4.535569	0.0002***
nre	0.326984	6.605186	0.0000***	0.321790	6.437511	0.0000***
im	-0.156273	-3.803942	0.0002***	-0.133753	-3.233888	0.0013***

Notes: ****, **, * denote statistical significance at the 1%, 5% and 10% levels, respectively. Cointegrating equation deterministics: intercept and trend. All variables are estimated in natural logarithms.

The results from FMOLS and DOLS long-run estimates corresponding to each model are reported in Table 6. All estimated coefficients can be interpreted as long-run elasticities, given that variables are expressed in natural logarithms. The long-run coefficients estimated from these techniques are very similar and have the same magnitude at the 1% and 5% significance levels. The EKC that assumes an inverted U-shaped relationship between emissions, economic growth and renewable energy is empirically supported for all estimated models.

For the model of panel A, all estimates are statistically significant at the 1% level and show that there is a strong long-run relationship between CO_2 emissions, economic growth, and renewable energy consumption. The panel result with FMOLS indicates that a 1% increase in real GDP increase emissions by approximately 5.17% and a 1% increase in the square of real GDP decrease emissions by 0.24%. In other words, the long-run elasticities of emissions with respect to per capita real GDP is equal to 5.17-0.23*y*. It means that an inverted U-shaped relationship between environmental degradation and real GDP per capita is validated. The long-run estimated coefficient related to renewable energy show that, a 1% increase in renewable energy consumption decrease emissions by 0.06%.

For the model of panel B (with non-renewable energy), the results reveal a strong long-run relationship between variables. The FMOLS panel result indicates that the long-run elasticities of CO_2 emissions with respect to per capita real GDP is approximately equal to 5.23-0.26*y*. Both FMOLS and DOLS estimation methods show that an increase in non-renewable energy consumption has a positive and statistically significant impact on emissions and a 1% increase in non-renewable energy consumption increase CO_2 emissions by approximately 0.3%.

For the models of panel C1 and panel C2, the results from the FMOLS and DOLS suggest that all coefficients are statistically significant and reveal a robust long-run links between the regressors. In addition, the estimated coefficients are very similar for both models (panels C1 and C2) and both estimation approaches (FMOLS and DOLS).

For the model with exports, the FMOLS panel estimation results indicate that the long-run elasticities of CO_2 emissions with respect to per capita real GDP is approximately equal to 3.68-0.17*y*. The impact of renewable energy consumption is negative and statistically significant at the 1% level, and a 1% increase in renewable energy decreases emissions by approximately 0.07%. The estimated coefficient of non-renewable energy consumption is positive and statistically significant at the 1% level. A 1% increase in non-renewable energy consumption increases emissions by 0.3%. For the trade variable, per capita real exports affect negatively emissions by approximately 0.12% with FMOLS method at the 1% significance level.

For the model with imports, the FMOLS panel estimation results indicate that the long-run elasticities of CO_2 emissions with respect to per capita real GDP is approximately equal to 4.04-0.18*y*. The impact of renewable energy consumption is negative and statistically significant at the 1% level, and a 1% increase in renewable energy decreases emissions by approximately 0.07%. The estimated coefficient of non-renewable energy consumption is positive and statistically significant at the 1% level. A 1% increase in the consumption of non-renewable energy increases emissions by 0.33%. A 1% increase in per capita real imports decreases per capita emissions by approximately 0.16%. These findings are not similar to the long-run estimates of Apergis et *al*. (2010) as they show that the renewable energy consumption coefficient is statistically significant but has a positive impact on emissions. Thus, renewable energy and trade openness can play an important role in reducing emissions.

Either for the model with exports or the model with imports, we show that the elasticities of CO_2 emissions, with respect to trade openness, is statistically negative. This result is not similar to the findings in Halicioglu (2009) for the case of Turkey because he shows that the elasticity of emissions with respect to trade openness is positive in the long-run. Also, our long-run elasticities of emissions with respect to trade are not the same as Jalil and Mahmud (2009)'s result. Indeed, these authors suggest that trade has a positive but statistically insignificant impact on emissions.

5. Concluding Remarks

In this paper, we investigate the long and short-run causal nexus between carbon dioxide emissions, economic growth, renewable and non-renewable energy consumption and trade openness (exports or imports) by using three different models. We aim to test the validity of the EKC hypothesis for a panel of twenty five OECD countries over the period 1980-2009 using cointegration techniques.

The short-run dynamic result reveals that there is a bidirectional causality between output and the square of output, a unidirectional causality running from the square of output to CO_2 emissions, a unidirectional causality running from the square of output to non-renewable energy consumption, and a unidirectional causality running from real exports to CO_2 emissions.

There is an indirect causality running from output to non-renewable energy consumption, which occurs through the square of output. Also, there is an indirect causality running from output to CO_2 emission, which occurs through the square of output. It is evident that emissions will be affected by economic growth and any increase in real GDP will grow up the level of emissions in the short-run. Contrary to other short-run dynamic findings, we found no causality between renewable and non-renewable energy consumption and emissions, and between renewable energy consumption and economic growth.

The FMOLS and DOLS long-run estimates support the U-shaped curve of EKC hypothesis between per capita GDP and emissions. The interesting result deduced from the long-run estimates suggests that, contrary to the positive sign of non-renewable energy consumption, the coefficient of renewable energy consumption is negative and statistically significant from each panel model. It explains that an increase in the consumption of renewable energy will decrease emissions of CO_2 which is not the same findings with the total energy use (renewable and non-renewable). Additionally, the impacts of trade variables are also negative and statistically significant. Thus, more trade openness leads to less CO_2 emissions.

As a policy implication, OECD countries should increase trade openness and uses of renewable energy to combat with global warming and reducing CO_2 emissions. By increasing the usage of renewable energy it will help to reduce energy dependency and promote energy security of energy importing countries too.

References

Acaravci, I., Ozturk, I. 2010. On the relationship between energy consumption, CO_2 emissions and economic growth in europe", Energy, 35, 5412-5420.

Ang, J. B., 2007. CO_2 emissions, energy consumption, and output in France. Energy Policy, 35, 4772-4778.

Apergis, N., Payne, J.E., 2009. CO_2 emissions, energy usage, and output in Central America. Energy Policy, 37, 3282-3286.

Apergis, N., Payne, J.E., 2010a. Renewable energy consumption and economic growth evidence from a panel of OECD countries. Energy Policy, 38, 656-660.

Apergis, N., Payne, J.E., 2010b. Renewable energy consumption and growth in Eurasia. Energy Economics, 32, 1392-1397.

Apergis, N., Payne, J.E., Menyah, K., Wolde-Rufael, Y., 2010. On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. Ecological Economics, 69, 2255-2260.

Apergis, N., Payne, J.E., 2011. The renewable energy consumption–growth nexus in Central America. Applied Energy, 88, 343-347.

Apergis, N., Payne, J.E., 2012. Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. Energy Economics, 34, 733-738.

Arouri, M.E.H., Youssef, A.B., M′henni, H., Rault, C., 2012. Energy consumption, economic growth and CO2 emissions in Middle East and North African countries. Energy Policy, 45, 342–349.

Breitung, J., 2000. The Local Power of Some Unit Root Tests for Panel Data, in: B.Baltagi (Ed.) NonStationary Panels, Panel Cointegration, and Dynamic Panels, Advances in Econometrics, 15, 161-178, JAI Press, Amsterdam.

Cole, M., 2005. Re-examining the pollution-income relationship: a random coeffi-cients approach. Economics Bulletin 14 (1), 1–7.

De Bruyn, S.M., Van den Bergh J. C. J. M., Opschoor, J. B., 1998. Economic growth and emissions: Reconsidering the empirical basis of environmental Kuznets curve. Ecological Economics, 25, 161–75.

Dickey, D.A., Fuller, W.A., 1979. Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association, 74, 427-431.

Engle, R.F., Granger C.W.J., 1987. Co-integration and error correction: Representation, estimation, and testing. Econometrica, 55, 251-276.

Fosten, J., Morley, B., Taylor, T., 2012. Dynamic misspecification in the environmental Kuznets curve: Evidence from CO_2 and SO_2 emissions in the United Kingdom. Ecological Economics, 76, 25-33.

Galeotti, M., Lanza, A., Pauli, F., 2006. Reassessing the environmental Kuznets curve for CO_2 emissions: a robustness exercise. Ecological Economics, 57, 152-163.

Grossman, G., Krueger, A., 1995. Economic growth and the environment. The Quarterly Journal of Economics, 110, 353-377.

Haggar, M.H., 2012. Greenhouse gas emissions, energy consumption and economic growth: A panel cointegration analysis from Canadian industrial sector perspective. Energy Economics, 34, 358-364.

Halicioglu, F., 2009. An econometric study of CO_2 emissions, energy consumption, income and foreign trade in Turkey. Energy Policy, 37, 1156-1164.

Heston, A., Summers, R., Aten, B., 2012. Penn world table version 7.1. Center of comparisons of production, income and prices at the University of Pennsylvania. Accessed at: https://pwt.sas.upenn.edu/php_site/pwt71/pwt71_form.php.

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

Jalil, A., Mahmud, S.F., 2009. Environment Kuznets curve for CO_2 emissions: A cointegration analysis for China. Energy Policy, 37, 5167-5172.

Jaunky, V.C, 2011. The CO_2 emissions-income nexus: Evidence from rich countries. Energy Policy, 39, 1228-1240.

Jayanthakumaran, K., Verma, R., Liu, Y., 2012. CO_2 emissions, energy consumption, trade and income: A comparative analysis of China and India. Energy Policy, 42, 450-460.

Kao, C., 1999. Spurious Regression and Residual-Based Tests for Cointegration in Panel Data. Journal of Econometrics, 90, 1-44.

Kao, C., Chiang, M.H., 2000. On the estimation and inference of a cointegrated regression in panel data, in: Baltagi, B.H., Fomby, T.B., Hill, R.C. (Eds.), Advances in Econometrics. Emerald Group Publishing Limited, 15, 179-222.

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

Mark, N.C., Sul, D., 2003. Cointegration vector estimation by panel DOLS and long-run money demand. Oxford Bulletin of Economics and Statistics, 65, 655-680.

Menyah, K., Wolde-Rufael, Y., 2010. CO_2 emissions, nuclear energy, renewable energy and economic growth in the US. Energy Policy. 38, 2911-2915.

Narayan, P.K., Narayan, S., 2010. Carbon dioxide and economic growth: panel data evidence from developing countries. Energy Policy, 38, 661–666.

Ouedraogo, N.S., 2013. Energy consumption and economic growth: Evidence from the economic community of West African states (ECOWAS). Energy Economics, 36, 637-647.

Ozcan, B. 2013. The nexus between carbon emissions, energy consumption and economic growth in Middle East countries: A panel data analysis. Energy Policy, 62, 1138-1147.

Ozturk, I., Acaravci, A. 2010. CO_2 emissions, energy consumption and economic growth in Turkey. Renewable and Sustainable Energy Reviews, 14, 3220-3225.

Pedroni, P., 1999. Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxford Bulletin of Economics and Statistics, 61, 653-678.

Pedroni, P., 2001. Purchasing power parity tests in cointegrated panels. The Review of Economics and Statistics, 83, 727-731.

Pedroni, P., 2004. Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. Econometric Theory, 20, 597-625.

Phillips, P.C.B., Perron, P., 1988. Testing for a unit root in time series regressions. Biometrika, 75, 335-346.

Sadorsky, P., 2009. Renewable energy consumption and income in emerging economies. Energy Policy, 37, 4021-4028.

Shahbaz, M., Lean, H.H., Shabbir, M.S., 2012. Environmental Kuznets Curve hypothesis in Pakistan: Cointegration and Granger causality. Renewable and Sustainable Energy Reviews, 16, 2947-2953.

Shahbaz, M., Ozturk, I., Afza, T., Ali, Am. 2013. Revisiting the Environmental Kuznets Curve in a Global Economy. Renewable and Sustainable Energy Reviews, 25, 494-502.

Shen, J., Hashimoto, Y., 2004. Environmental Kuznets curve on country level: evidence from China. Discussion Paper 04-09, at: /http://www2.econ.osaka-u.ac.jp/library/global/dp/0409.pdfS.

Suri, V., Chapman, D., 1998. Economic growth, trade and energy: implications for the environmental Kuznets curve. Ecological Economics, 25, 195-208.

Tugcu, C.T., Ozturk, I., Aslan, A., 2012. Renewable and non-renewable energy consumption and economic growth relationship revisited: Evidence from G7 countries. Energy Economics, 34, 1942-1950.

World Bank, 2013. World Development Indicators. Accessed at: http://www.worldbank.org/data/onlinedatabases/onlinedatabases.html.