Acaravci, Ali; Akalin, Guray

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International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2017, 7(5), 34-43.

Environment–economic Growth Nexus: A Comparative Analysis of Developed and Developing Countries#

Ali Acaravci[1]*, Guray Akalin[2]

[1]Faculty of Economics and Administrative Sciences, Mustafa Kemal University, Hatay, Turkey, [2]Faculty of Economics and Administrative Sciences, Dumlupınar University, Kutahya, Turkey. *Email: acaravci@hotmail.com

ABSTRACT

This study aims to examine the interaction between carbon emissions, income, and trade openness in developed and developing countries for the period from 1980 to 2010 by using recently developed panel data econometric methods. The results are as follows: (i) There is an evidence of the cross-sectional dependence for each variable. (ii) The cross-sectionally augmented and Smith et al.'s panel unit root tests are indicate that all variables are stationary at their first difference. (iii) A Durbin–Hausman cointegration test shows that there exists a long-term relationship between variables. (iv) The results from the common correlated effect estimator presents that there is evidence of the validity of the environmental Kuznets curve (EKC) hypothesis in developed countries. (v) The EKC hypothesis is not valid in developing countries.

Keywords: Economic Growth, Environmental Kuznets Curve, Panel Data Analysis
JEL Classification: C33, O57, Q43, Q53, Q56

This paper depends on the results of Guray AKALIN's Master Thesis: "Enviromental kuznets curve validity of the developed and developing countries-comparative analysis of panel data."

1. INTRODUCTION

The primary goal of economic activities is to increase human welfare and rapid economic growth is seen as a way to accomplish this goal. However, when production increases the use of resources while the relative cost of production factors diminish, wastes generated by the production and consumption process raise the environmental cost. Moreover, population growth, urbanization, and the increasing of use of non-renewable energy can overtake the carrying capacity of the environment. As a result, many environmental problems have begun to emerge that includes climate change; global warming; air, water, and soil pollution; loss of biodiversity; and forest destruction. As environmental problems have become more severe, the nexus between environmental degradation and economic growth becomes an increasingly important issue (Tutulmaz, 2015).

The environmental Kuznets curve (EKC) hypothesis, which implies an inverted-U relationship between environmental degradation and economic growth, has become the center of this research. According to the EKC hypothesis, economic growth is both cause of and solution to environmental degradation. For this reason, testing the EKC hypothesis becomes prominent to economic growth and environmental policies. The EKC hypothesis that inspired from the Kuznets curve, has been first proposed and tested by Grossman and Krueger (1991). They found evidence that the environmental degradation first increases as per capita income rise, but then starts to decrease after turning point in per capita income. Their study has been also confirmed by Shafik and Bandyopadhyay (1992) and Panayotou (1993). Stern (2004), Dinda (2004), Shahbaz et al. (2015), Ozturk and Al-mulali (2015), Tang et al. (2016) and Gill et al. (2017) have provided extensive review surveys of the studies that tested the nexus between economic growth and environmental pollution. While Johansson and Kriström (2008) have emphasized that the literature on the EKC is insufficient and this topic needs more empirical investigation. Stern (2004) argued that the issues of the EKC should be revisited by using new models and decompositions with different panels and time series data sets.

However, few scholars as Panayotou (1993) believe that the EKC is caused by upgrading from the adjustment of economic structures (Tiwari et al., 2013). Some of these authors have underlined the roles of three different effects in the EKC (Tutulmaz, 2015), that can be listed as scale effects, structural effects and technique effects (Grossman and Krueger, 1991; Stern, 2004; Song et al., 2008): (i) Scale effect means that using more natural resources in the production process leads to the destruction of nature while technology is constant, which is defined as environmental degradation. (ii) According to the structural effect, economic development passes through stages starting from the preliminary upgrade from an agriculture system to the rapid development of high-grade, industrial structures with high-pollution industries and then finally turns to more information-concentrated industries, which leads to improvements in environmental quality. (iii) In the technique effect that discovered by Stokey (1998), economic growth can break through one threshold point after arriving at a certain stage of economic development. Hence, at a low-income level, only the high pollution technique can be used but, after crossing the threshold point of economic development, cleaner technologies can be adopted which lowers the degradation in environmental quality.

Further, another approach to explain the EKC relationship is the income elasticity of demand for environmental quality. The demand for a clean environment increases while real income per capita increases (Lopez and Islam, 2008). Lieb (2002) argued that an increase in income improves the level of education, and this creates awareness about the environment. Moreover, an increase in income distribution has positive effects on the environment. Finally, he mentions that the policies implemented after the internalization of external effects, substitution between the pollutants, and finally a crisis in the energy sector will affect the shape of the EKC and its turning point.

In this context, this study aims to test the EKC hypothesis in developed and developing countries for the period from 1980 to 2010 by using panel data econometric methods. To test the EKC hypothesis, the common correlated effect (CCE) estimator, developed by Pesaran (2006), has been employed in a multivariate framework which includes carbon emissions, gross domestic product (GDP) per capita, and trade openness rate (% of GDP). The rest of the paper is organized as follows: Section 2 summarizes literature on the EKC hypothesis; Section 3 describes the model and the data; Section 4 explains the methodology and Section 5 reports the empirical results; and finally, Section 6 concludes the paper.

2. LITERATURE REVIEW

Many empirical studies attempt to test the validity of the EKC by using a quadratic or cubic equation. This equation examines the relationship between the per capita incomes with a variety of air pollution indices. A basic reduced (income-reduced) form of an EKC model and interpretation is summarized as by De Bruyn and Heintz (1999):

$$E_{it} = \beta_1 + \beta_2 Y_{it} + \beta_3 Y_{it}^2 + \beta_4 Y_{it}^3 + \beta_5 Z_{it} + \varepsilon_{it} \quad (1)$$

Where E represents environmental pressure or environmental pollution; Y represents economic development; Z is other variables; i and t are country and time indices; and ε is the error term. Equation (1) lets us test several forms of environment–economic development/growth relationships that can be described as follows:

i) If $\beta_2=\beta_3=\beta_4=0$, there is a flat pattern (no relationship) between Y and E.
ii) If $\beta_2>0$ and $\beta_3=\beta_4=0$, there is a monotonic increasing relationship (a linear relationship) between Y and E.
iii) If $\beta_2<0$ and $\beta_3=\beta_4=0$, there is a monotonic decreasing relationship between Y and E.
iv) If $\beta_2>0$, $\beta_3<0$ and $\beta_4=0$, there is an inverted-U-shaped relationship.
v) If $\beta_2<0$, $\beta_3>0$ and $\beta_4<0$, there is an inverted N-shaped relationship.
vi) If $\beta_2>0$, $\beta_3<0$ and $\beta_4>0$, there is a cubic polynomial or N-shaped relationship.

A large number of econometric studies have used equation (1) to test for the emergence of an EKC in a wide variety of income-based environmental pressure/pollution levels (Dinda, 2004). The studies that investigate the relationship between the environment and economic growth have begun in 1990 as a reaction to environmental issues. Most of this works have tested the EKC hypothesis. In these studies, different models, methods, data sets, and variables have been used. Most studies in this area have been examined by us and are shown in the following Table 1. The results of the literature review indicate that there is no consensus on this issue.

3. MODEL AND DATA

This paper employs the form of a cubic model in order to test EKC hypothesis that can be introduced as follows:

$$co_{2it} = \beta_{1i} + \beta_2 gdp_{it} + \beta_3 gdp_{it}^2 + \beta_4 gdp_{it}^3 + \beta_5 tr_{it} + \varepsilon_{it} \quad (2)$$

Where co_2, carbon emissions per capita (measured in metric kilograms), is the environmental indicator that is directly related to major issues such as climate change; gdp is the per capita income (constant 2005 USD), and to improve the structure of an econometric model, trade openness rate (% of GDP), tr, is used as a control variable. The annual time series data is taken from the World Bank, World Development Indicators (2014) online for the period from 1980 to 2010 in the form of balanced panel data. The following two samples are used: 40 high-income countries and 33 upper middle-income countries. The 40 high-income countries include Antigua and Barbuda, Australia, Austria, Bahamas, Bahrain, Barbados, Belgium, Canada, Chile, Cyprus, Denmark, Equatorial Guinea, Finland, France, Greece, Hong Kong SAR (China), Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Macao, Malta, the Netherlands, New Zealand, Norway, Oman, Portugal, Saudi Arabia, Singapore, Spain, Saint Kitts, Sweden, Switzerland, Trinidad, the United Kingdom, the United States, and Uruguay. The 33 upper middle-income countries include Albania, Algeria, Argentina, Belize, Botswana, Brazil, Bulgaria, China, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, Fiji, Gabon, Grenada, Hungary, Jordan,

Table 1: Selected empirical studies on the EKC hypothesis

Authors	Sample and period	Method	Dependent variable	Independent variable	Results
Grosmann and Krueger (1991)	Nafta countries 1977, 1982, 1988	PDA	SO_2 SPM	GDP	1. N relationship for SO2 EKC is not valid 2. Decreasing linear relationship for SPM
Shafik and Bandyopadhyay (1992)	149 countries 1960-1990	PDA	Clean water City water sanitation SO_2 The amount of dissolved oxygen in the river Changes in forest areas Deforestation Fecal coliform in the river Mid-air particles CO_2 10. Urban Waste	GDP	1. EKC is not valid 2. EKC is not valid 3. EKC is valid (Inverted-U) 4. EKC is not valid 5. EKC is not valid 6. EKC is not valid 7. EKC is valid (Inverted-U) 8. EKC is valid (Inverted-U) 9. EKC is not valid 10. EKC is not valid
Selden and Song (1994)	30 countries 1979-1987	PDA	SO_2 NO_2 SPM CO_2	GDP	1. EKC is valid (inverted-U) 2. EKC is valid (inverted-U) 3. EKC is valid (inverted-U) 4. EKC is valid (inverted-U)
Panayatou (1997)	30 countries 1982-1994	PDA	NO_2 PM10 SO_2 Deforestation	GDP	1. EKC is valid (inverted-U) 2. EKC is valid (inverted-U) 3. EKC is valid (inverted-U) 4. EKC is valid (inverted-U)
Moomaw and Unhruh (1997)	16 countries 1950-1992	PDA	CO_2	GDP	EKC is valid (inverted-U)
Kaufman et al. (1998)	23 countries 1974-1989	PDA	SO_2	GDP	1. EKC is valid (inverted-U)
Torras and Boyce (1998)	42 countries 1977-1991	PDA	SO_2 Mid-air particles	GDP	1. N relationship for SO2 EKC is not valid 2. EKC is not valid
De Bruyn et al. (1998)	4 countries 1960-1993	PDA	SO_2 CO_2 NO_2	GDP	1. EKC is not valid 2. EKC is not valid 3. EKC is not valid
Agras and Chapman (1999)	34 countries 1971-1989	PDA	CO_2	GDP	EKC is valid (inverted-U)
Barret and Graddy (2000)	32 countries 1977, 1982, 1998	PDA	SO_2	GDP	N relationship for SO_2 EKC is not valid
Dijkgraaf and Vollebergh (2001)	OECD countries 1960-1997	PDA	CO_2	GDP	EKC is not valid
Stern and Common (2001)	73 countries 1960-1990	PDA	SO_2	GDP	EKC is valid (inverted-U)
Mason and Swanson (2003)	29 countries 1976-1988	PDA	CFC	GDP	EKC is valid (inverted-U)
Cole (2004)	18 OECD countries 1980-1997	PDA	SO_2	GDP	EKC is valid (inverted-U)
Dinda et al. (2000)	33 countries 1979-1990	PDA	SO2	GDP	EKC is valid (inverted-U)
Ang (2007)	France 1984-2004	TSA	CO_2	GDP	EKC is valid (inverted-U)

(*Contd...*)

Table 1: (*Continued*)

Authors	Sample and period	Method	Dependent variable	Independent variable	Results
He and Richard (2009)	Canada 1948-2004	TSA	CO_2	GDP	EKC is not valid
Narayan and Narayan (2010)	43 developing countries 1980-2004	PDA	CO_2.	GDP	EKC is valid in the Middle East and South Asian countries
Acaravci and Ozturk (2010)	19 Europian Countries 1960-2005	TSA, ARDL	CO_2	EC and GDP	EKC is valid in the Italy and Denmark
Pacini (2010)	138 countries 2007	CSDA	CO_2	HDI	EKC is valid (inverted-U)
Sanglimsuwan (2011)	63 countries 1990, 1995, 2000	PDA	CO_2	GDP	EKC is valid on only in the short term
Farhani and Rejeb (2012)	15 Mena countries 1973-2008	PDA	CO_2	EC and GDP	EKC hypothesis is supported weakly
Han and Lee (2013)	19 OECD countries 1981-2009	PDA	CO_2	GDP	EKC is valid (inverted-U)
Shahbaz et al. (2013)	Romania 1980-2010	TSA, ARDL	CO_2	GDP, EC and TR	EKC is valid
Mamun et al. (2014)	136 countries divided into five major income groups	PDA	CO_2	GDP, TR, sectoral output	EKC is valid for LIC, LMIC and UMIC countries EKC is not valid for HIOECD and HINOECD countries
Mensah (2014)	6 African Countries 1971-2009	ARDL	CO_2	EC and GDP	EKC only valid for Ghana
Menegaki and Tsagarakis (2015)	33 European member and candidate state countries 1990-2010	PDA, ABB	RES, Oil, Gas, Coal	GDP, Energy Intensity, Education, Techonology, Demography, Science	EKC is valid (inverted-U) for both of the RES and Coal variables EKC is not valid (ınverted-U) for both of the oil and gas variables
Ahmed et al. (2016)	Brazil, India, China, S. Africa 1970-2013	Pedroni, FMOLS	CO_2	GDP, NSC, URBAN	EKC is not valid
Dogan and Turkekul (2016)	USA 1960-2010	ARDL	CO_2	GDP, FD, TR, URBAN	EKC is not valid
Ozturk et al. (2016)	144 countries 1988-2008	GMM	Ecological footprint	Tourism, energy consumption, trade openness, urbanization	the EKC hypothesis is more present in the upper middle- and high-income countries than the other income countries
Saidi and Mbarek (2017)	19 emerging countries 1990-2013	GMM	CO_2	GDP, TR, urban	EKC is valid (inverted-U)

TSA: Time series analysis, PDA: Panel data analysis, ARDL: Autoregressive distributed lag, CSDA: Cross section data analysis, GMM: Generalised method of moments, FMOLS: Fully modified ordinary least squares, ABB: ArellanoBond-Bover estimator. GDP: Per capita GDP, EC: Per capita energy consumption, TR: Trade openess, FD: Financial development, URBAN: Urbanisation, RES: Renewable energy sources, NSC: Natural gas consumption, HDI: Human development index, OECD: Organization for economic cooperation and development, LIC: Lower income countries, LMIC: Lower middle-income countries, UMIC: Upper middle-income countries, HIOECD: High-income OECD countries, HINOECD: High-income non-OECD countries, Nafta: North american free trade agreement, MENA: Middle east and north africa, SO_2: Sulfur dioxide, SPM: Smoke and mid-air particles, CO_2: Carbon dioxide, NO_2: Nitrogen dioxide, PM10: Particulate matter, CFC: Chlorofluorocarbon

Malaysia, Mauritania, Mexico, Panama, Peru, Seychelles Islands, South Africa, Santa Lucia, Saint Vincent, Thailand, Tonga, Tunis, Turkey, and Venezuela. These countries were selected according to data available from related income groups.

4. METHODOLOGY

4.1. Testing the Cross-sectional Dependency

Conventional panel unit root tests which are also known as first-generation like those of Hadri (2000), Levin–Lin–Chu (LLC, 2002), and Im–Pesaran–Shin (IPS, 2003) assume that cross sections are independent and are not able to consider the cross section dependency. This is particularly true of panels with a large cross section dimension (*N*). In the case of panels where *N* is small (say 10 or less) and the time dimension of the panel (*T*) is sufficiently large between sections of panel models, it can cause serious correlations (Pesaran, 2004). The cross-sectional dependency in error terms can be caused by several reasons. The first of these neglects spatial and common effect, while the other neglects the relationship between socio-economic networks in the panel model. It does not consider the cross-sectional dependence that occurs due to these reasons and the estimates made by the traditional panel estimator can produce misleading or even inconsistent parameters (Chudik and Pesaran, 2013). Therefore, the cross-dependency should be tested on the basis of both models and variables. If cross-sectional dependence exists in the variables or model, using the first-generation tests may cause the first type of error. For a more reliable econometric estimation approach, researchers must explore cross-sectional dependency in each series and model.

Breusch and Pagan (1980) proposed the following Lagrange multiplier test statistic to test for cross-sectional dependency:

$$CD_{LM1} = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{p}_{ij}^{2} \tag{3}$$

where $\hat{p}_{ij}$ is the estimated correlation coefficient among the residuals obtained from individual ordinary least squares (OLS) estimations. Under the null hypothesis of no cross-sectional dependency with a fixed *N* (number of cross-sections) and time period $T\to\infty$, the statistic has chi-square asymptotic distribution with *N(N-1)/2* degrees of freedom. However, this test is not applicable with a large *N*. To overcome this problem, the Lagrange multiplier statistic developed by Pesaran (2004) can be used as shown in the following equation:

$$CD_{LM2} = \left(\frac{1}{N(N-1)}\right)^{1/2}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\left(T\hat{p}_{ij}^{2}-1\right) \tag{4}$$

Under the null hypothesis of no cross-sectional dependency with first $T\to\infty$ and then $N\to\infty$, this test statistic is an asymptotic standard normal distribution. Even though the CD_{LM2} test overcomes the drawback of CD_{LM1}, it likely exhibits substantial size distortions when $N/T\to\infty$. When *N* is large and *T* is small, Pesaran (2004) proposed to use of the following cross-sectional dependency test:

$$CD_{LM3} = \left(\frac{2T}{N(N-1)}\right)^{1/2}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{p}_{ij} \tag{5}$$

Under the null hypothesis of no cross-sectional dependency with $T\to\infty$ and $N\to\infty$ in any order, the CD_{LM3} test is asymptotically distributed as standard normal (Nazlıoglu et al.*,* 2011).

4.2. Panel Unit Root Tests

This paper employs two panel unit root tests developed by Pesaran (2007) (cross-sectionally augmented Dickey–Fuller [CADF]) and Smith et al. (2004) (hereafter Smith bootstrap) in order to investigate the stationarity properties and determine the order of integration of the variables.

The most important feature of the CADF panel unit root test is to give reliable results whether *N*>*T* or *T*>*N*. Furthermore, this test is a heterogeneous test and provides separate results for each section (Pesaran, 2007).

The Smith bootstrap panel unit root approach includes five test statistics which are called as *t**, $\overline{LM}$, $\overline{Max}$, $\overline{Min}$, and $\overline{WS}$. The *t** test is the bootstrap version of the IPS panel unit test and is calculated as $t^{*} = N^{-1}\sum_{i=1}^{N}t_i$. The $\overline{LM}$ test has been developed by Solo (1984) and tests statistic is calculated as $\overline{LM} = N^{-1}\sum_{i=1}^{N}LM_i$. The $\overline{Max}$ test has been developed by Leybourne (1995) and is calculated as $\overline{Max} = N^{-1}\sum_{i=1}^{N}Max_i$. The $\overline{Min}$ test is a more powerful variant of the LM statistic and is calculated as $\overline{Min} = N^{-1}\sum_{i=1}^{N}Min_i$. Finally, we examine the $\overline{WS}$ test developed by Pantula et al. (1994). The first test does not consider the cross-sectional dependence. We use bootstrap blocks of $m=10^2$. All four tests are constructed with a unit root under the null hypothesis and heterogeneous autoregressive roots under the alternative, which indicates that a rejection should be taken as evidence in favor of stationarity for at least one country (Smith et al. 2004).

4.3. Panel Cointegration and Estimating of the Long-run Coefficients

This paper employs Durbin-Hausman cointegration test in order to investigate the existence of long-run relationship between variables. Durbin-Hausman test allows the cross-sectional dependency in model and gives reliable results when some of explanatory variables are I(0). This test contains two statistics as follows: The DH-group and the DH-panel statistics. While the DH-group statistic assumes that the autoregressive parameters are heterogeneous and produces results under this assumption; the DH-panel statistic assumes that the autoregressive parameters are homogeneous and produces results under this assumption. In a case when both test statistics reject the null hypothesis; these results indicate the existence of co-integration for the entire panel (Westerlund, 2008).

Once the cointegration relationship is established, the next step is to estimate the long-run parameters. To estimate panel cointegration parameters, various methods have been proposed, namely panel OLS, panel dynamic OLS, and panel fully modified OLS. However, none of these consider cross-sectional dependence. To consider the cross-sectional dependence, we use the CCE estimator developed by Pesaran (2006). Moreover, the CCE estimator has satisfactory small sample properties even under a substantial degree of heterogeneity and dynamics or relatively small values of *N* and *T* (Pesaran, 2006). This model's estimators consider the effects of factors that are not included in the econometric model coupled with a cross section of each unit's time vector regression equations.

The CCE estimator assumes that the effects of unobserved common effects and independent variables are stationary and external, but this approach continues to yield consistent estimation and valid inference even when common factors are unit root processes (Pesaran, 2006). The CCE also allows for individual specific errors to be serially correlated and heteroscedastic. In the model, the common correlated effects pooled statistics are used for the panel and are calculated as follows:

$$\widehat{b}_p = \left(\sum_{i=1}^{N} \theta_i X_i' \bar{M}_w X_i \right)^{-1} \sum_{i=1}^{N} \theta_i X_i' \bar{M}_w y_i \qquad (6)$$

5. EMPIRICAL RESULTS

5.1. Cross-sectional Dependence Tests Results

Table 2 presents that the null hypothesis of no cross-sectional dependency is rejected for both countries. This provides strong evidence for the existence of cross-sectional dependency across developed and developing countries. This means that, whether developed or developing countries, any development on the environmental–income–trade nexus in one or more countries affects other countries.

5.2. Panel Unit Root Tests Results

As there is cross-sectional dependence in all variables, the stationarity properties of the series will be investigated by the second generation unit root tests. In this study, a CADF panel unit root test developed by Pesaran (2007) and a bootstrap panel unit root test developed by Smith et al. (2004) has been used to determine the stationarity properties of the variables. Cross-sectional dependence in the model has been also found, so cointegration analysis must that take into account cross-sectional dependence is used. The CIPS panel unit root test results for the developed and developing countries show that the null hypothesis for all variables is accepted at their levels of variables but the null hypothesis for all variables is rejected at their first differences. This means that all variables are stationary at their first differences (Table 3).

The Smith bootstrap panel unit root test results for both the developed countries indicate that the null hypothesis is accepted for all levels of the variables (Table 4). The test statistics for the first-differences strongly reject the null hypotheses, which imply that the variables are stationary in the first-difference form. The Smith bootstrap unit root test results depend on only the intercept model and intercept-trend model for developing countries indicate that the null hypothesis is accepted for all levels of the variables except for the *tr* variables. The test statistics for the first-differences strongly reject the null hypotheses, which imply that the variables are stationary in the first-difference form.

Table 2: Cross-section dependence test results for variables and models

Tests	co_2	gdp	gdp^2	gdp^3	tr	Model
Developed countries						
CD LM1	1178.543 (0.000)	1336.885 (0.000)	691.085 (0.000)	695.753 (0.000)	1344.930 (0.000)	1583.734 (0.000)
CD LM2	10.090 (0.000)	14.099 (0.000)	5.019 (0.000)	5.162 (0.000)	14.303 (0.000)	20.349 (0.000)
CD LM3	2.433 (0.000)	3.806 (0.000)	−3.679 (0.000)	−3.688 (0.000)	1.536 (0.062)	11.765 (0.000)
Developing countries						
CD LM1	713.000 (0.000)	782.046 (0.000)	789.537 (0.000)	785.617 (0.000)	674.793 (0.000)	742.548 (0.000)
CD LM2	5.693 (0.000)	7.818 (0.000)	8.048 (0.000)	7.928 (0.000)	4.517 (0.000)	6.602 (0.000)
CD LM3	−2.565 (0.005)	−2.906 (0.002)	−2.921 (0.002)	−2.892 (0.002)	−1.830 (0.034)	−1.494 (0.068)

P values are in ( )

Table 3: CIPS panel unit root test results

Models	co_2	gdp	gdp^2	gdp^3	tr
Developed countries					
Level	−2.066	−2.006	−1.937	−1.883	−2.156
1st difference	−3.707	−2.869	−2.874	−2.859	−3.415
Model contains only intercept; critical value (1%) is −2.23					
Level	−2.272	−1.877	−1.836	−1.807	−2.640
1st difference	−3.997	−3.190	−3.212	−3.203	−3.451
Model contains constant and trend; critical value (1%) is −2.73					
Developing countries					
Level	−1.860	−1.729	−1.648	−1.641	−2.17
1st difference	−3.543	−3.222	−3.081	−3.119	−3.596
Model contains only intercept; critical value (1%) is −2.30					
Level	−1.867	−2.112	−2.004	−1.962	−2.405
1st difference	−3.667	−3.600	−3.523	−3.491	−3.577
Model contains constant and trend; critical value (1%) is −2.81					

Critical values (1%) are taken from Pesaran (2007) Table 2b. The maximum lag length is taken as 4 and optimal lag length is determined by the Schwarz information criteria

5.3. Panel Cointegration Test Results and the Estimated Long-run Coefficients

The unit root test results present that the integrated degree of the variables is one and this situation indicates a possible long-run cointegrating relationship among the carbon emissions per capita (co_2), income per capita (*gdp*), and trade openness (*tr*). Therefore, a cointegration test is performed at the next stage.

The results of the Westerlund–Durbin–Hausman panel cointegration test are presented in Table 5. The results show that there is a long-run relationship between the variables for both the developed and developing countries under the assumption of homogeneity in both are heterogeneous. This means that a long-term relationship exists among the non-stationary variables.

Table 6 presents the results from the CCE method for both the developed and developing countries. The results for the developed countries show that the findings are compatible with expectations and the literature. While the coefficients for the gdp^3 and *tr* variables are statistically insignificant, the coefficient for the *gdp* variable is statistically significant and positive, and the coefficient for gdp^2 variable is statistically significant and negative at a 5% level of significance. According to these results, there is evidence for validity of the EKC hypothesis in the developed countries. The level of carbon emissions first increases with income, stabilizes, and then declines. Thus, there appears to be an inverted U-shaped relationship between carbon emissions per capita and real GDP per capita in the developed countries.

The results for developing countries show that the coefficient of the *tr* variable is statistically insignificant, the coefficient of the *gdp* variable is significant and negative, the coefficient of the gdp^2 variable is significant and positive, and the coefficient of the gdp^3 variable is significant and negative at a 5% level of significance. These results indicate that the EKC hypothesis is not valid in the developing countries. There is an inverse N relationship between environmental pollution and income. The empirical results indicate that trade openness has no statistically significant impact on carbon emissions for both the developed and developing countries. This means that the increase of trade volume does not produce more carbon emissions.

6. CONCLUSIONS AND POLICY IMPLICATIONS

Since the early 1970s, especially after the United Nations Conference on the Human Environment in 1972, the relationship between production and environmental concerns has been handled by different methods in different disciplines. This is because the environment is of vital importance for human life, and they are confronted with serious environmental problems. The most important of these problems are as follows: The risk of going over the environmental pollution assimilation capacity; the difficulty in return of natural balance in the environment; large-scale health problems caused by environmental pollution; rapid depletion of natural resources; global warming and climate change, and the resulting related natural disasters such as floods; the reduction of biodiversity, air pollution, and soil pollution.

Empirical studies on the environmental pollution–economic growth nexus explore the validity of the EKC hypothesis which states that environmental pollution will increase up to a certain threshold of income growth, and after this threshold, will begin to decrease due to the demand for a clean environment and structural and technological inputs. If the EKC hypothesis is valid, economic growth is both cause of and solution to environmental pollution. This approach is often used when arguing that countries should not compromise economic growth policies to reduce environmental effects. The EKC hypothesis is not valid in cases where economic growth that increased production is the only cause of environmental pollution. This has accelerated the search to replace the neoclassical growth strategy. Especially highlighted by the 1992 UNCED conference in Rio de Janeiro, a win-win approach to understanding the appropriate account of the ecological paradigm has gained importance in recent years. Therefore, the validity of the EKC hypothesis is an important issue in formulating economic growth policies for all countries.

In this study, the following two samples are used: (i) 40 high-income countries (OECD members and non-members) and (ii) 33 upper middle-income countries. These countries are selected according to data available from related income groups. The results from the dynamic panel data methods are as follows: (i) The Durbin–Hausman cointegration test shows that there is a long-term relationship between variables. (ii) The results from the CCE estimator indicate that there is evidence of validity of the EKC hypothesis in developed countries. (iii) The EKC hypothesis is not valid in the developing countries.

These results show that economic growth is sufficient enough to safeguard environmental quality for developed countries. However, developing countries have not yet reached income levels high enough to be able to derive their turning points. Therefore, to reduce environmental pollution that comes with economic growth, developing countries should give importance to R&D activities and institutionalization of environmental awareness. An increase in environmental awareness is imperative and developing and developed countries must not forget the fact that the natural world of tomorrow will be created today. Also, our findings show that trade liberalization is not harmful for the environment in developed and developing countries. This means that the increase of trade volume will not produce more carbon emissions. Despite the results obtained for the developed countries, we cannot assume that environmental betterment will continue to accompany further growth of per capita income in developed countries. So that, future studies can examine the relationship between economic growth and other pollutants. Because, along with the economic growth it may increase the amount of other pollutants.

The main contribution of this paper is that we avoid using econometric model that don't taking into account cross sectional dependency. Previous, studies generally use econometric models that assume that cross sections are independent and are not able to consider the cross section dependency. However, in this case,

Table 4: Smith bootstrap panel unit root test results

	Developed countries									
Level[a]						**1st difference[a]**				
	co_2	gdp	gdp^2	gdp^3	tr	co_2	gdp	gdp^2	gdp^3	tr
Max	−0.701 (0.899)	−0.369 (0.951)	−0.426 (0.931)	−0.421 (0.937)	−1.354 (0.143)	−4.474 (0.000)	−2.658 (0.000)	2.807 (0.000)	2.766 (0.000)	−4.260 (0.000)
LM	3.758 (0.106)	3.809 (0.207)	3.621 (0.288)	3.396 (0.372)	3.020 (0.453)	13.201 (0.000)	7.233 (0.000)	−2.661 (0.000)	2.655 (0.000)	12.293 (0.000)
MinLM	2.143 (0.226)	1.568 (0.747)	1.512 (0.781)	1.424 (0.836)	2.447 (0.140)	12.530 (0.000)	6.711 (0.000)	7.235 (0.000)	7.082 (0.000)	12.160 (0.000)
WS	−0.887 (0.908)	−0.528 (0.977)	−0.545 (0.973)	−0.491 (0.983)	−1.471 (0.199)	−4.653 (0.000)	−2.873 (0.000)	−2.878 (0.000)	−2.879 (0.000)	−4.448 (0.000)
Level[b]						**1st difference[b]**				
	co_2	gdp	gdp^2	gdp^3	tr	co_2	gdp	gdp^2	gdp^3	tr
Max	−1.453 (0.919)	−1.328 (0.866)	−1.362 (0.838)	−1.351 (0.856)	−2.032 (0.208)	−4.606 (0.000)	−2.896 (0.000)	−2.867 (0.000)	−2.828 (0.000)	−4.205 (0.000)
LM	4.831 (0.674)	3.924 (0.920)	3.971 (0.910)	3.923 (0.915)	5.536 (0.282)	14.034 (0.000)	8.206 (0.000)	8.078 (0.000)	7.826 (0.000)	12.406 (0.000)
MinLM	3.195 (0.871)	2.768 (0.905)	2.845 (0.890)	2.758 (0.904)	4.446 (0.218)	13.149 (0.000)	7.731 (0.000)	7.643 (0.000)	7.505 (0.000)	12.245 (0.000)
WS	−1.941 (0.835)	−1.832 (0.872)	−1.867 (0.838)	−1.853 (0.849)	−2.303 (0.232)	−4.962 (0.000)	−3.210 (0.000)	−3.193 (0.000)	−3.174 (0.000)	−4.520 (0.000)
	Developing countries									
Level[a]						**1st difference[a]**				
	co_2	gdp	gdp^2	gdp^3	tr	co_2	gdp	gdp^2	gdp^3	tr
Max	−0.709 (0.907)	−0.192 (1.000)	−0.426 (0.931)	−0.421 (0.937)	−1.242 (0.101)	−4.900 (0.000)	−3.573 (0.000)	2.807 (0.000)	2.766 (0.000)	−4.509 (0.000)
LM	2.759 (0.728)	1.000 (0.952)	3.621 (0.288)	3.396 (0.372)	3.577 (0.195)	14.634 (0.000)	10.501 (0.000)	−2.661 (0.000)	−2.655 (0.000)	13.005 (0.000)
MinLM	1.912 (0.425)	1.520 (0.801)	1.512 (0.781)	1.424 (0.836)	2.644 (0.042)	13.680 (0.000)	9.768 (0.000)	7.235 (0.000)	7.082 (0.000)	12.758 (0.000)
WS	−0.868 (0.929)	−0.307 (1.000)	−0.545 (0.973)	−0.491 (0.983)	−1.535 (0.049)	−5.124 (0.000)	−3.823 (0.000)	−2.878 (0.000)	−2.879 (0.000)	−4.732 (0.000)
Level[b]						**1st diffefence[b]**				
	co_2	gdp	gdp^2	gdp^3	tr	co_2	gdp	gdp^2	gdp^3	tr
Max	−1.763 (0.435)	−1.552 (0.736)	−1.558 (0.728)	−1.593 (0.693)	−2.128 (0.043)	−4.925 (0.000)	−3.800 (0.000)	−3.803 (0.000)	−3.762 (0.000)	−4.547 (0.000)
LM	4.964 (0.574)	4.191 (0.923)	4.105 (0.936)	4.148 (0.934)	6.368 (0.042)	15.105 (0.000)	11.517 (0.000)	11.466 (0.000)	11.251 (0.000)	13.426 (0.000)
MinLM	1.812 (0.514)	3.145 (0.858)	3.216 (0.832)	3.378 (0.749)	5.196 (0.018)	14.023 (0.000)	10.796 (0.000)	10.769 (0.000)	10.600 (0.000)	13.153 (0.000)
WS	−2.174 (0.336)	−1.882 (0.862)	−1.894 (0.854)	−1.925 (0.811)	−2.468 (0.022)	−5.299 (0.000)	−4.117 (0.000)	−4.117 (0.000)	−4.074 (0.000)	−4.898 (0.000)

[a]Models contain only constant. [b]Models contain constant and trend. P values are in ( ). The maximum lag length is taken as 4, and the optimal lag length is determined by the general to specific approach. Probability values are obtained from 5000 bootstrap distribution

Table 5: Panel cointegration test results

Variables	Developed countries		Developing countries	
	t stat. (NW)	P value	t stat. (NW)	P value
Durbin-H group stat.	128.629	0.000	1356.295	0.000
Durbin-H panel stat.	12.241	0.000	3.908	0.000

Table 6: The estimated long-run coefficients for the EKC model

Variables	Developed countries		Developing countries	
	Coefficients	t stat (NW)	Coefficients	t stat (NW)
gdp	50.4683	2.0989	−101.9750	−3.3968
gdp^2	−10.5701	−1.7850	29.9381	3.4916
gdp^3	0.7278	1.5025	−2.8935	−3.5465
tr	0.0501	0.7160	−0.0872	−1.5952
Critical values (5%)		±1.645		±1.645

EKC: Environmental Kuznets curve

traditional panel estimator can produce misleading or even inconsistent parameters (Chudik and Pesaran, 2013). While, there is no study in the literature using sample types and econometric models as same as this paper, it is possible to say that our findings are consistent with Moomaw and Unhruh (1997), Ang (2007), Shahbaz et al. (2013), Mensah (2014), Ahmed et al. (2016). On the contrary, our findings are not consistent with He and Richard (2009), Narayan and Narayan (2010), Farhani and Rejeb (2012), Mamun et al. (2014), Dogan and Turkekul (2016), Saidi and Mbarek (2017).

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