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Is There an Environmental Kuznets Inverted-U Shaped Curve?

Summary: This study examines the relationship among carbon dioxide (CO_2) emissions, income, energy consumption, trade openness, financial development and institutional quality based on the environmental Kuznets curve (EKC) hypothesis in 151 countries for the period 1996-2010, using the pooled ordinary least squares methods. The results support cubic specification of the EKC hypothesis, which assumes a cubic polynomial inverted-U shaped relationship between income and environmental degradation. Other empirical results indicate that energy consumption, trade openness, financial development and institutional quality are significant variables in explaining CO_2 emissions.

Key words: CO_2 emissions, Environmental Kuznets curve, Economic growth, Panel data analysis, Inverted-U shape.

JEL: C33, F18, F43.

Given the current debates on global warming as one of the environmental problems, the relationship between economic growth and the environment are getting more attention from economic policy makers. Several empirical studies suggest that the environment at first worsens economic development in its early stages up to a threshold level, but then improve at higher levels. This is the so-called environmental Kuznets curve (EKC) hypothesis. It was established by Simon Smith Kuznets, whom had postulated a similar relationship between income inequality and *per capita* income in 1955's.

The EKC concept emerged in the early 1990s with Gene M. Grossman and Alan Krueger's pioneer study and Nemat Shafik and Sushenjit Bandyopadhyay's background study for the World Development Report 1992. In this respect, the 1990s saw the advent of EKC hypothesis and an explosion of studies that empirically tested it for several pollutants.

Gene M. Grossman and Alan Krueger (1991) explained an inverted-U shaped relationship between the environmental degradation and income level with three different channels (scale effect, composition effect, and technique effect). In the early stages of economic development/growth inevitably the greater use of natural resources and emission of pollutants increases environmental degradation (scale effect). Economic growth, thus, exhibits a scale effect with a negative impact on the environment. But, economic growth has a positive impact on the environment through composition effect and technique effect as well. As income increases, cleaner activities or less polluting activities gradually would occur in economic structure (composition effect). As a wealthy nation can afford to spend more on R&D, technological progress occurs with economic growth. So, the dirty and obsolete technologies are replaced by new and cleaner technology. Environmental quality along with the increase in the capacity of higher income countries to face this technological substitution improves (technique effect) (Soumyananda Dinda 2004; Matias Piaggio and Emilio Padilla 2012).

As can be understood from this transition mechanism, the process produced the inverted-U shape for the relationship between gross domestic product (GDP) and environmental degradation and it has provoked a vast empirical research over the last decade.

The aim of this paper is to examine the empirical relationship between economic growth and the environment at different stages of economic development. The remainder of this paper is organized as follows. Section 1 outlines the previous literature, Section 2 discusses the data set and the methodology and presents the empirical findings and Section 3 is the concluding part of the paper.

1. Literature Review

In this section, we have reviewed literature examining the relationship between environmental pollution and *per capita* income. Several studies have revealed an inverted-U shaped EKC relationship between carbon dioxide and income using data from various countries utilizing various econometric methods. For example, Hans J. B. Opschoor (1990) provides intuition to support a cubic shaped relationship. He argues that once technical efficiency improvements in resource use or abatement opportunities have been exhausted or have become too expensive, further income growth will result in net decline in environmental quality (Don J. Webber and Dave O. Allen 2010).

Theodore Panayotou, Alix Peterson, and Jeffrey Sachs (2000) tested the validity of the EKC hypothesis in seventeen industrialized countries between 1870 and 1994. Using a feasible generalized square method, the results of the study revealed a significant and positive correlation between income *per capita* and income *per capita* squared and carbon dioxide emissions.

Madhusudan Bhattarai and Michael Hammig (2001) examined the relationship between institutions and the EKC for deforestation across 66 countries comprising of Latin America, Africa, and Asia. Empirical results show strong evidence of an EKC relationship between income and rate of deforestation for all three continents over the period 1972-1991. Furthermore, the results show that improvements in institutional quality and in governance significantly reduce deforestation.

Aurelia Bengochea-Morancho, Francisco Higón-Tamarit, and Inmaculada Martínez-Zarzoso (2001) analysed cubic specification of the EKC for the European Union countries over 16 years of data using parametric fixed and random effects panel estimation techniques. Their study supported the presence of an inverted-U shaped EKC for the European Union countries.

Ming-Feng Hung and Daigee Shaw (2006) developed the simultaneity model in order to estimate the relationship between pollution and *per capita* income in Taiwan. Using a fixed effects specification, the results of the study showed that *per capita* income has significant effects on pollution. Furthermore, it is found that population density, which is used as another independent variable, has significant negative effects on pollution.

Alexandra Leitão (2006) investigated the effects of corruption and income on sulphur emissions by using a wide cross-national panel of countries. The empirical findings show that the higher degree of the country's corruption, higher *per capita* income at the turning point, suggesting different income-pollution paths across countries due to corruption. Consequently, Leitão (2006)'s results support the validity of the EKC hypothesis for sulphur emissions.

Shehryar Rashid (2009) analysed the relationship between carbon dioxide emissions and GDP growth in the BRIC countries and the United States over the period 1981-2006. Rashid (2009) used industry value added share in GDP, energy consumption and foreign direct investment (FDI) inflow besides GDP *per capita* and GDP *per capita* squared as independent variables in the EKC regression. According to the empirical results, the existence of an EKC was supported in the United States and the BRIC countries for the period 1981-2006. Also, the results showed that energy consumption is positively related to carbon dioxide emissions, while FDI inflow is negatively related to carbon dioxide emissions in the BRIC countries.

Artur Tamazian, Juan Pineiro Chousa, and Krishna Chaitanya Vadlamannati (2009) investigated the relationship between financial development and environmental degradation. Their research findings revealed that financial development causes a decrease in carbon dioxide emissions *per capita*. Hence, they concluded that financial liberalization can lead to investment and R&D which will lead to environmental improvement.

Biswo N. Poudel, Krishna Paudel, and Keshav Bhattarai (2009) tested the EKC hypothesis for carbon dioxide emissions in 15 Latin American countries over a 21-year period (1980-2000). Using parametric and semi-parametric specifications, the study revealed that the EKC follows an N-shaped pattern in Latin America.

Ayşe Arı and Fatma Zeren (2011) investigated whether the EKC hypothesis is valid for the Mediterranean countries with the panel data method over the period between 2000-2005. The obtained empirical results showed that carbon dioxide emissions can increase at higher levels of *per capita* income. Also, the study that investigated the effects of the population density and energy consumption of carbon dioxide emissions showed that the population density and energy consumption positively affected carbon dioxide emissions.

Thomas Dietz, Eugene A. Rosa, and Richard York (2012) investigated the relationship between gross domestic product (GDP) *per capita* and ecological intensity of well-being using panel data on 58 nations. They find that there exists a U-shaped relationship between GDP *per capita* and the environmental intensity of human well-being.

Thomas Jobert, Fatih Karanfil, and Anna Tykhonenko (2012) tested the EKC hypothesis by using the fixed effects model in 55 countries. Taking into account heterogeneity, Jobert, Karanfil, and Tykhonenko (2012) introduced *per capita* primary energy consumption to the standard quadratic form of EKC regression. The empirical results suggest that the EKC hypothesis is rejected for 49 out of 51 countries. Furthermore, the results reveal that an increase in GDP decreases emissions in the high-income countries and that emissions and GDP are positively correlated in the low-income countries.

Contrarily, several studies reject the inverted-U shaped relationship existing between carbon dioxide emissions and income. For example, Nemat Shafik and Sushenjit Bandyopadhyay (1992) claim that there exists a monotonically increasing relationship between carbon dioxide emissions and income for 118 countries. William R. Moomaw and Gregory C. Unruh (1997) and Elbert Dijkgraff and Herman Vollebergh (1998) used data from OECD countries from 1950 to 1992 and from 1960 to 1997, respectively. Both studies reject the existence of a quadratic relationship between carbon dioxide emissions and income.

Amy K. Richmond and Robert Kaufmann (2006) use the price of light fuel oil for industries in sixteen OECD countries over the period 1978-1997. They found evidence in favour of the EKC hypothesis, but it vanishes when energy prices are included in the standard EKC regression model.

Serkan Çınar (2011) examined the relationship between *per capita* carbon dioxide emissions and *per capita* GDP of 31 OECD countries over the period 1971-2007. Using panel data method, the study showed that there exists a cointegration relationship between income and carbon dioxide emissions.

Behnaz Saboori, Jamalludin Bin Sulaiman, and Saidatulakmal Mohd (2012) focused on the dynamic relation among carbon dioxide emissions, economic growth, energy consumption and foreign trade in Indonesia for the period 1971-2007, using the autoregressive distributed lag methodology. The econometric analysis found no evidence supporting the existence of an inverted-U shaped EKC. Furthermore, the long-run results reveal that foreign trade is the most significant variable in explaining carbon dioxide emissions in Indonesia followed by energy consumption and economic growth.

Natina Yaduma, Mika Kortelainen, and Ada Wossink (2015) applied the quantile fixed effects technique in exploring the EKC for carbon dioxide emissions within two groups of economic development (OECD and non-OECD) and six geographical regions (West, East Europe, Latin America, East Asia, West Asia and Africa). Their results revealed the existence of a significant EKC in OECD and Western groups.

Sayed Ahmad Al and Siok Kun Sek (2013) investigated the validity of the inverted-U EKC hypothesis for the data spanning from the year 1961 to 2009 in two groups of economies (developed and developing countries). Using different environmental variables such as CO_2, SO_2, BOD, SPM_{10} and GHG, the findings of the study reveal evidence of the existing inverted-U shape in most cases. In addition, the study reveals that the turning point in developed countries is higher than of the developing countries.

Jie He and Patrick Richard (2010) considered the analysis of carbon dioxide emissions and GDP *per capita* in Canada using annual data which spanned from 1948 to 2004. The results from semi-parametric model support the presence of the EKC between GDP *per capita* and *per capita* carbon dioxide emissions. However, their study revealed that the relationship between carbon dioxide emissions *per capita* and GDP *per capita* is monotonically increasing only when GDP is nonlinear.

Rajeev Goel, Risto Herrala, and Ummad Mazhar (2013) focused on the variables of carbon dioxide emissions, population, population density, corruption perceptions index, literacy rate and energy efficiency to validate the EKC hypothesis. Using pooled annual data for over 100 nations over the years 2004-2007, the results of the study show that both shadow economy and corruption reduce recorded carbon dioxide emissions. Also, the study found that population, population density, and literacy rate did not significantly affect carbon dioxide emissions. Furthermore, the results revealed that greater energy efficiency reduces emissions while greater openness of world trade and greater economic prosperity are associated with more emissions.

Bayram Yıldırım (2013) analysed the effects of trade openness and income on carbon dioxide emissions for 32 countries consisting of 10 developing, 10 developed, 7 European countries and top 5 economies. According to the results, it is observed that there is a significant increase in carbon dioxide emissions due to the trade of developing countries. Also, the results have confirmed the EKC hypothesis for each country group.

Miguel Rodríguez and Yolanda Pena-Boquete (2014) use carbon dioxide emissions *per capita* discharged into the environment, *per capita* GDP at purchasing power parity, and the set of energy prices, including the prices for coal, oil products, and natural gas to validate the EKC hypothesis. Their results found no evidence supporting the existence of the EKC hypothesis. The empirical results revealed that there exists a monotonic and positive relationship between carbon dioxide emissions and GDP when the relative energy price changes are included in the standard EKC regression model.

2. Data and Methodology

2.1 Source of Data

In this study, we are interested to empirically investigate the determinants affecting carbon dioxide emissions. The variables considered in this study are *per capita* CO_2 emissions, real *per capita* GDP, energy consumption, trade openness, money and quasi money as % of GDP as a proxy variable of financial development, political stability, government effectiveness and three dummy variables identifying Middle East, North Africa, Pakistan and Afghanistan (MENAP) countries, Brazil, Russia, India, China and South Africa (BRICS) countries and the Organization of Islamic Cooperation (OIC) member states. All data are annual, cover the years 1996 to 2010, and extend to 151 countries (see the Appendix). The period has been chosen as 1996-2010 because of the availability of all data and the reason for the selection 151 countries is that the selected countries have non-missing values between the time period of 1996 to 2010. Therefore, the selection of countries for which data are presented reflects the reality of data availability.

All data were collected from World Bank's World Development Indicators (World Bank 2015)[1]. CO_2 emissions (*lco2pc*) is measured in metric tonnes *per capita*, the real *per capita* GDP (*lgdpper*) is in constant 2000 US dollars, energy consumption (*lenc*) is measured as kg of oil equivalent *per capita*, trade openness ratio (*lopen*) is the total value of real import and real export as a percentage of real GDP, financial development (*lfd*) is measured as money and quasi-money as % of GDP, political stability (*pol*) and government effectiveness (*gov*) have been obtained from the World Bank's Worldwide Governance Indicators produced by Daniel Kaufmann, Aart Kraay, and Massimo Mastruzzi (2010).

2.2 Model and Econometric Methodology

2.2.1 Model

Following the traditional EKC reduced form framework, this paper models *per capita* CO_2 emissions as a cubic polynomial function of *per capita* GDP as follows in Equation (1) (with subscript *i* denoting a country and *t* denoting a year):

$$
\begin{aligned}
lco2pc_{it} &= \alpha_0 + \beta_1 . \lg dpper_{it-1} + \beta_2 . \lg dpper^2{}_{it-1} + \\
&+ \beta_3 . \lg dpper^3{}_{it-1} + \beta_4 . lenc_{it-1} + \beta_5 . lopen_{it} + \beta_6 . lfd_{it} + \\
&+ \beta_7 . pol_{it} + \beta_8 . gov_{it-1} + \beta_9 . MENAP + \beta_{10} . OIC + \beta_{11} . BRICS + \varepsilon_{it},
\end{aligned}
\quad (1)
$$

where *lco2pc* is the log of *per capita* CO_2 emissions; *lgdpper*, $lgdpper^2$, $lgdpper^3$ denote the log of *per capita* GDP and it's squared and cubic terms, respectively; *lenc* is the log of energy consumption *per capita*; *lopen* represents the log of trade openness ratio; *lfd* is the log of financial development; *pol* and *gov* represent political stability and government effectiveness, respectively.

Equation (1) provides us for testing several forms of economic growth-environment relationships:

(i) $\beta_1 = \beta_2 = \beta_3 = 0$, *no relationship*;
(ii) $\beta_1 \succ 0, \beta_2 = \beta_3 = 0$, *a monotonic increasing relationship*;
(iii) $\beta_1 \prec 0, \beta_2 = \beta_3 = 0$, *a monotonic decreasing relationship*;
(iv) $\beta_1 \succ 0, \beta_2 \prec 0, \beta_3 = 0$, *an inverted-U shaped relationship*;
(v) $\beta_1 \prec 0, \beta_2 \succ 0, \beta_3 = 0$, *a U-shaped relationship*;
(vi) $\beta_1 \succ 0, \beta_2 \prec 0, \beta_3 \succ 0$, *N-shaped relationship*;
(vii) $\beta_1 \prec 0, \beta_2 \succ 0, \beta_3 \prec 0$, *opposite to the N-shaped relationship*;
(viii) $\beta_1 \succ 0, \beta_2 \succ 0, \beta_3 \prec 0$, *a cubic polynomial inverted-U shaped relationship*;
(ix) $\beta_1 \prec 0, \beta_2 \prec 0, \beta_3 \succ 0$, *a cubic polynomial U-shaped relationship*.

[1] **World Bank.** 2015. World Development Indicators. https://data.worldbank.org/datacatalog/world-development-indicators (accessed January 01, 2015).

Table 1 Descriptive Statistics

Variable	Mean	Std. dev.	Maximum	Minimum	Obs.
lco2pc	0.652430	1.674455	4.227344	-4.218.767	2244
lgdpper	7.976085	1.892093	11.38187	0.000000	2244
lopen	4.323326	0.507174	6.070853	2.542389	2244
lfd	3.839868	0.773568	6.507099	0.728782	2244
pol	-0.112428	0.987294	1.670000	-3.180.000	2244
lenc	-1.193.098	2.257204	4.618258	-6.742.241	2244
gov	0.055973	1.006843	2.430000	-2.320.000	2244

Source: Authors' calculation.

Table 1 presents descriptive statistics of the data used in this paper. As a result, there is no sampling bias in the data. The means of all variables used for the empirical analysis are close neither to their minimum nor maximum value, which indicates that there is no disproportion. Moreover, the standard deviations of the variables are large and the values are widely dispersed around the mean.

2.2.2 Methods

We apply the panel data analysis to investigate the determinants affecting carbon dioxide emissions through the Kuznets curve framework. Panel data help to detect the dynamics of changes in short time series. Moreover, it gives more informative data, more variability, less colinearity among the variables, more degrees of freedom and so, more efficiency (Badi Baltagi 2005).

(a) Homogeneity and cross-sectional dependency analysis

As a first step, this study applies M. Hashem Pesaran and Takashi Yamagata's (2008) homogeneity test in order to determine whether or not slope coefficients are homogenous in the empirical model. A homogenous panel data model (or pooled model) is a model in which all coefficients are common while a heterogenous panel data model is defined as a model in which all parameters (constant and slope coefficient) vary across individuals (Christophe Hurlin 2010). Pesaran and Yamagata (2008) proposed *delta_tilde* test for testing slope homogeneity. Under the null hypothesis of slope homogeneity with the condition of $(N, T) \rightarrow \infty$, so long as $\sqrt{N}/T \rightarrow \infty$ and the error terms are normally distributed, the *delta_tilde* statistic has an asymptotic standard normal distribution. The small sample properties of the statistic can be improved under the normally distributed errors with bias-adjusted statistic (*delta_tilde_adjusted*) suggested by Pesaran and Yamagata (2008).

As a second step, we tested the existence of cross-sectional dependence across countries. Pesaran (2006) showed that ignoring cross-section dependency leads to substantial bias and size distortions in the estimation of the relationship between two variables. In this study, we apply Pesaran, Aman Ullah, and Yamagata (2008)'s (PUY) LM test:

$$PUY\text{'s } LM = \sqrt{\frac{2}{n(n-1)}}.\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\frac{(T-k).p_{ij}^2 - \mu_{T_{ij}}}{\varphi_{T_{ij}}} \quad , \tag{2}$$

where $\mu_{T_{ij}} = \frac{1}{T-k}.tr(M_i M_j)$ is the exact mean of $(T-k).p_{ij}^2$ and $M_i = I - X_i.(X'_i.X_i)^{-1}.X'_i$ where $X_i = (x_{i1},...,x_{iT})'$ contains T observations on the k regressors for the i-th individual regression. PUY's LM is asymptotically distributed as N(0,1), under the null, with $T \to \infty$ first, and then $n \to \infty$ (Baltagi, Qu Feng, and Chihwa Kao 2012).

(b) Unit root analysis

Having analysed cross-section dependency, we then control whether there exists unit root in the series in order to get unbiased estimations. Several different panel unit root tests are available. The literature on panel unit root testing distinguishes between first generation unit root tests assuming cross-sectional independence between panel units and second generation unit root tests taking into account of possible cross-section dependence.

A number of investigators, notably Gangadharrao Soundalyarao Maddala and Shaowen Wu (MW) (1999), Andrew Levin, Chien-Fu Lin, and Chia-Shang James Chu (2002), Kyung So Im, Pesaran, and Yongcheol Shin (2003), have developed panel-based unit root tests that are similar to tests applied to individual series. The common assumption of these tests is that there is cross-section independence among panel units. Levin, Lin, and Chu (LLC) (2002)'s test assume that each autoregressive coefficient is the same for all units, while Im, Pesaran, and Shin (IPS) (2003)'s test allow for heterogeneous autoregressive coefficients. From this aspect, therefore, IPS differs from LLC because all the series in the alternative hypothesis are stationary processes in LLC, while in IPS some series can still be non-stationary in the alternative hypothesis. The IPS test allows for residual serial correlation and heterogeneity of the dynamics and error variances across units. The IPS testing procedure is written as follows:

$$\Delta Y_{i,t} = \mu_i + \rho_i.Y_{i,t-1} + \delta_i.t + \phi_t + \sum_{j=1}^{k}\alpha_j.\Delta Y_{i,t-j} + \varepsilon_{it} \,. \tag{3}$$

Testing for unit root in the panel is based on the Augmented Dickey-Fuller (ADF) statistics averaged across groups. The hypothesis of IPS may be specified as follows:

$$H_0 : \rho_i = 0\,, \quad H_A : \rho_i \prec 0\,, \text{ for all } i.$$

The alternative hypothesis allows that for some (but not all) of individual series to have unit roots. IPS compute separate unit root tests for the N cross-section units. IPS define their t-bar statistics as a simple average of the individual ADF statistics, t_i, for the null as:

$$\bar{t} = \sum_{i=1}^{N} t_i / N \,. \tag{4}$$

It is assumed that t_i are i.i.d and have finite mean and variance and E(t_i), Var(t_i) is computed using Monte-Carlo simulation technique. Other test MW is based on a combination of the *p*-values of the test statistics for a unit root in each cross-sectional unit. The null and alternative hypotheses are the same as those of the IPS test. Unlike the IPS test, the procedure advocated by MW does not require a balanced panel and it is non-parametric (Laszio Kónya 2001). MW define λ test statistic as follows:

$$\lambda = -2\sum_{i=1}^{n} \ln p_i \sim \chi^2_{2n} , \tag{5}$$

where π_i denotes the *p*-value from the ADF test on the i^{th} time series. MW and Choi approaches have the same framework. In Choi (2001) proposes a *Z* test and shows that when *N* also tends to infinity, *Z* may be standardized as follows (Haluk Erlat 2009):

$$Z = \frac{1}{2\sqrt{N}} \sum_{\mathrm{i}=1}^{N} -2 \ln p_{\mathrm{i}} - 2 , \tag{6}$$

where *Z* have an asymptotic N(0,1) distribution.

We apply the approaches of Maddala and Wu (1999), Choi (2001) and Im, Pesaran, and Shin (2003), for the series with cross-sectional independence while we employ the bootstrap $\bar{t}$ test of Vanessa Smith et al. (2004) for the series with cross-sectional dependence. The test $\bar{t}$ is a bootstrap version of the first generation panel unit root test developed by Im, Pesaran, and Shin (2003). The null hypothesis for the test $\bar{t}$ is that of a unit root for the panel of countries, the alternative, that of heterogeneous autoregressive roots less than unity for each country. Thus, rejection of the null indicates that at least one country in the panel does not have a unit root and is stationary. As the final step of this paper, in estimating the relationship between the selected variables to constituting a Model (1), we use pooled regression estimation technique.

2.3 Econometric Results

As outlined earlier, testing for both cross-sectional dependence and slope homogeneity is crucial for selecting the appropriate estimator. Hence, we tested first the homogeneity of the Model (1) by using Pesaran and Yamagata's (2008) homogeneity test. The results of this test are reported in Table 2. The *p*-values clearly indicate rejection of the null hypothesis of the slope homogeneity hypothesis. Thus, reports support country-specific heterogeneity (for both *delta_tilde* and *delta_tilde_adjust*). The rejection of slope homogeneity implies that if the panel unit root analysis imposes homogeneity restrictions on the variable of interest, there will be misleading inferences. Therefore, we take into account the tests that do not impose homogeneity restrictions on the variable in the empirical part of the study.

Table 2 Pesaran and Yamagata (2008)'s Homogeneity Test

	Test statistic	*p*-value
delta_tilde	20.820	0.000
delta_tilde_adjusted	27.760	0.000

Source: Authors' calculation.

Like testing slope homogeneity, taking into account cross-sectional dependence in empirical analysis is critical as the economies of countries around the world become increasingly integrated over time. To investigate the existence of cross-sectional dependence, we applied LM_{adj} test of Pesaran, Ullah, and Yamagata (2008). Based on the results from Table 3, it is clear that the null hypothesis of no cross-sectional dependency is not rejected at the 0.05 significance level by all variables in the dataset except the log of financial development (*lfd*) series.

Table 3 Cross-Section Dependence Test Results

LM_{adj} (Pesaran, Ullah, and Yamagata 2008)				
Variable	**Constant**		**Constant and trend**	
	Statistic	***p*-value**	**Statistic**	***p*-value**
lgdpper	0.780	0.218	0.625	0.266
lenc	-1.517	0.935	-0.537	0.704
lco2pc	-2.520	0.994	-1.961	0.975
lopen	1.092	0.137	0.742	0.229
lfd	3.323	0.000***	2.007	0.022**
pol	-1.219	0.889	-0.632	0.736
gov	-0.998	0.841	-1.079	0.860

Notes: ***, **, and * indicate rejection of the null hypothesis at 1, 5, and 10 percent levels of significance, respectively.

Source: Authors' calculation.

Based on the results from Table 2 and Table 3, we used the bootstrap $\bar{t}$ test of Smith et al. (2004) for the series with cross-sectional dependence as the panel unit root test. On the other hand, we apply the panel unit root tests of Maddala and Wu (1999), Choi (2001) and Im, Pesaran, and Shin (2003), for the series with cross-sectional independence. The next step after the homogeneity and cross-sectional dependence analyses is to test the existence of unit roots in the dataset.

Table 4 demonstrates the following four types of panel unit root tests: Im, Pesaran, and Shin (2003), Fisher type test using ADF and PP tests (Maddala and Wu 1999; Choi 2001; Smith et al. 2004).

The results of unit root tests for the series are illustrated in Table 4. Test results, assuming cross-sectional independence in Table 4 show that the IPS testing procedure and Fisher type tests reject the null hypothesis of nonstationarity at the 5% level for *lgdpper*, *lenc*, *gov* when these variables are lagged by one period. On the other hand, the IPS test and both Fisher tests strongly reject the null hypothesis of unit root for *pol* and *lopen* at level. In the case of *lco2pc*, the null hypothesis of nonstationarity is rejected by the IPS test and the MW test at a 10% level. In the case of *lfd* containing cross-sectional dependence, the *p*-value of Smith et al. (2004)'s *t*-bar test is significantly less than 0.05 significance level. Thus, rejection of the null indicates that at least one country in the panel does not have a unit root and is stationary. Accordingly, test statistics confirm unit roots as the null hypothesis of nonstationary for all variables except for *pol*, *lopen*, *lco2pc* and *lfd* in the case of one lag and therefore confirm first differences to be I(0). On the other hand, *pol*, *lopen*, *lco2pc* and *lfd* are stationary at level, i.e. these variables are I(0).

Table 4 Results of Unit Root Tests

Variable	IPS		MW		Choi	
	Statistic	*p*-value	Statistic	*p*-value	Statistic	*p*-value
lgdpper	6.412	1.000	268.717	0.916	6.812	1.000
lenc	2.577	0.995	310.801	0.351	2.700	0.996
lco2pc	-1.627	0.051*	390.820	0.000***	-1.055	0.145
lopen	-3.277	0.000***	391.145	0.000***	-3.218	0.000***
pol	-3.342	0.000***	385.933	0.000***	-3.109	0.000***
gov	-1.274	0.101	320.889	0.217	-1.159	0.123
Δlgdpper	-14.221	0.000***	726.752	0.000***	-12.805	0.000***
Δlenc	-22.952	0.000***	1025.53	0.000***	-20.679	0.000***
Δgov	-28.852	0.000***	1306.60	0.000***	-25.907	0.000***
The bootstrap panel unit root test ($\bar{t}$), Smith et al. (2004)						
Variable	$\bar{t}$ statistic	$\bar{t}$ *p*-value				
lfd	-2.976	0.001				

Notes: A rejection of the null hypothesis of non-stationarity for a given panel indicates that at least one country in the panel does not have a unit root and is stationary. The bootstrap *p*-values are, in each case, based on 5000 simulations.

Source: Authors' calculation.

Having established the stationarity of the series, then we proceed to test the existence of the EKC hypothesis for model (1) using the pooled OLS estimation technique. This method assumes that for a given country, observations are uncorrelated and, the errors are homoscedastic across countries and time. The results of panel estimation are summarised in Table 5.

Table 5 Results for Panel Least Squares Method, White Cross-Section Standard Errors and Covariance (d.f. Corrected)

Variable	Coefficient	Std. error	*t*-statistic	Prob.
c	-2.241507	0.078631	-28.50677	0.0000***
Δ (lgdpper)	0.200541	0.074741	2.683152	0.0074***
Δ (lgdpper)^2	0.011440	0.001974	5.794415	0.0000***
Δ (lgdpper)^3	-0.002771	0.000875	-3.167514	0.0016***
pol	0.472645	0.008435	56.03192	0.0000***
Δ gov	0.167580	0.010082	16.62174	0.0000***
lopen	0.744368	0.013213	56.33463	0.0000***
lfd	0.034227	0.015636	2.188950	0.0287**
Δ lenc	0.370753	0.002449	151.3726	0.0000***
OIC	-0.574773	0.019755	-29.09464	0.0000***
MENAP	1.151287	0.020518	56.11204	0.0000***
BRICS	0.414639	0.028470	14.56396	0.0000***
Turning points EKC	-1.816		4.532	

Diagnostic test statistics
Wooldridge autocorrelation test prob. = 0.256
JB normality test prob. = 0.53
LM heteroskedasticity test prob. = 0.230

Notes: Δ is first difference operator and ***, **, * indicate the statistical significance at 1%, 5%, and 10% levels respectively.

Source: Authors' calculation.

When we look at the diagnostic test statistics in Table 5, we can see the model is statistically reliable. Since there are no heteroscedasticity and autocorrelation problems in the model, the estimation results are reliable and interpretable. From Table 5, we can also see that all the coefficients are statistically significant in difference from zero and hence, all the *lgdpper* (*lgdpper*, *lgdpper*^{2}, *lgdpper*^{3}) and other explanatory variables seem to play a significant role in explaining the CO_2 fluctuations. The findings with regard to *lgdpper*, *lgdpper*^{2} support those in Table 5 - greater economic prosperity increases CO_2 emissions while *lgdpper*^{3} has the opposite effect on CO_2 emissions. According to these results, we can say that there is a cubic polynomial inverted-U shaped relationship between CO_2 emissions and *lgdpper* in 151 countries of interest. Consequently, the EKC emission reversal at higher incomes is clearly present in the data, with appropriate signs on the model coefficients. Also, Table 5 provides the results of turning points obtained from the estimation model (1). The turning point level of income, where CO_2 emissions are at a maximum level, can be found using the following formula: $x = \frac{\beta_2 \pm \sqrt{\beta_2{}^2 - 3.\beta_3\beta_1}}{3.\beta_3}$. The turning points of the EKC curve are calculated as -1.816 and 4.532.

Other empirical findings of the study are as follows: as the political stability and the government effectiveness increased, CO_2 emissions also significantly increased. This finding is consistent with the expectation that political stability and government effectiveness, which are proxy variables of institutional quality, will be weakly related to revenue performance for low and middle-income countries and that better institutional quality will trigger economic growth. In addition to these findings, it finds that trade openness index, financial development, and energy consumption are positively related to CO_2 emissions. Finally, when making a comparison among the coefficients of the three dummy variables on CO_2 emissions, we obtain the results that MENAP's and BRICS's coefficients are positive and statistically significant while the OIC's coefficient is negative and statistically significant. MENAP nations have also shown higher emissions than other countries. This result confirms that these countries have higher economic prosperity than the other countries.

3. Conclusions

Global environmental issues are getting more attention, especially the increasing threat of global warming and climate change. Today, climate scientists predict that humankind's increasing emission of greenhouse gases will induce a long-term change in the world's climate.

Human activities intensify the blanketing effect through the release of greenhouse gases. For instance, the amount of carbon dioxide in the atmosphere has increased by about 35% in the industrial era, and this increase is known to be due to human activities, primarily the combustion of fossil fuels and removal of forests. Thus, humankind has dramatically altered the chemical composition of the global atmosphere with substantial implications for climate (Intergovernmental Panel on Climate Change - IPCC 2007).

This paper investigated the relationship between *per capita* carbon dioxide emissions and economic growth in 151 countries based on the EKC hypothesis for the period 1996-2010 by incorporating energy consumption, trade openness, political stability, government effectiveness and financial development.

The positive and a negative coefficient of real *per capita* GDP, real *per capita* GDP squared and real *per capita* GDP cubed respectively, have indicated a cubic polynomial inverted-U shaped relationship between *per capita* carbon dioxide emissions and *per capita* real GDP. This confirms that carbon dioxide emissions increase at the initial level of economic growth, after then reach a turning point and continues to increase and finally decreases with the higher level of economic growth. Therefore, our results support the EKC hypothesis in the cubic specification. The elasticity of carbon dioxide emission with respect to energy consumption is 0.370 and highly significant. This implies that for each 1% increase in energy consumption *per capita*, carbon dioxide emissions will rise by 0.370%. The coefficient of trade openness is 0.744. This coefficient is indicating that 1% increase in trade openness will lead to 0.744% increase in *per capita* carbon dioxide emissions. Similarly, the coefficient of financial development is also positive and the magnitude of the coefficient is estimated by 0.034. Moreover, it is observed that political stability and government effectiveness that are used as proxy variables of institutional quality have a positive and significant effect on carbon dioxide emissions. This finding is supported by the notion that greater economic prosperity that is triggered by institutional quality is associated with greater development, which increases carbon dioxide emissions.

Consequently, greenhouse gas emissions, representing climate change are one of the greatest environmental, social and economic threats facing the planet. Carbon emissions that are the primary source of greenhouse gas emissions can be reduced through a reduction in the rate of land conversion and deforestation, better control of wildfires, adoption of alternatives to the burning of crop residues after harvest, reduction of emissions from commercial fishing operations, and more efficient energy use by forest dwellers, commercial agriculture and agro-industries (Food and Agriculture Organization of the United Nations - FAO 2008).

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