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New Evidence of Environmental Kuznets Curve Hypothesis in Developing Countries

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Abstract

New indexes of environment and institutions are constructed following principal component analysis (PCA), while non-linear panel regression is employed. This study attempts to estimate a non-linear impact of GDP per capita on the environment following the Environmental Kuznets Curve (EKC) Hypothesis for 97 developing countries during 1991-2014. The study reveals that a traditional EKC shows a U-shaped relationship under static panels, with both quadratic and cubic regressions. Interestingly, the inverted U-shaped occurs when a traditional EKC is estimated by the dynamic panels, with both quadratic and cubic regressions. Moreover, the EKC model is inverted U-shaped following static and dynamic panels, with both quadratic and cubic regressions under institutions. Indeed, the institutions significantly contribute to express EKC in developing countries. Policymakers should formulate environmental policies following climate change mitigation in the environmental sustainability framework, improve the quality of institutions, and increase macroeconomic management to anticipate external shocks such as openness, globalization, and FDI inflows.

Keywords: Environment, Institutions, GDP, EKC, non-linear panel regression
JEL Classification: E02, Q51, Q56

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1. Introduction

The increasing impacts of carbon dioxide (CO_2) emission and climate change on the economy have been extensively studied in the literature. Various policies to reduce CO_2 emission levels have also been conducted by policymakers following the Kyoto Protocol and Paris Agreement to adopt climate change mitigation within the framework of environmental sustainability (Churchill et al., 2018; and Sarkodie & Strezov, 2018). Conceptually, the literature argues that the Environmental Kuznets Curve (EKC) hypothesis can be a basic argument of the relationship between environmental quality and per capita income following an inverted-U shaped relationship as the result of the first study by Grossman & Krueger (Churchill et al., 2018; Sarkodie & Strezov, 2018; and Chen et al., 2019). Thus, the current study aims to estimate the EKC for 97 developing countries that have problems with CO_2 emission levels and climate change during 1991-2014.

The Environmental Kuznets Curve (EKC) is a concept that explains the relationship between income inequality and per capita income in the form of an inverted U-relationship formulated by Kuznets in 1955 (Churchill et al., 2018). Since the 1990s, EKC has been developed in environmental studies that describe the inverted U-shaped relationship between per capita income and environmental quality. Sarkodie & Strezov (2018) have schematically described an inverted U-shaped relationship as presented in Figure 1. Moreover, Ali et al. (2020) have noted that previous empirical studies established environmental quality indicators, namely greenhouse gas (GHG) in the form of carbon dioxide (CO_2), sulfur dioxide (SO_2), methane (CH_4), sulfur hexafluoride (SF_6), nitrous oxide (N_2O), and ecological footprint. Environmental indicators can also be proxied by several data, including Google trends index of pollution, general government expenditure on environmental protection, and SO_2 emission (Chen et al., 2019). In more general, the current study sets out environmental quality indicators in 97 developing countries as follows: CO_2 emissions (transport, other sectors, manufacturing industries and construction, electricity and heat production, residential buildings and commercial and public services), nitrous oxide emissions, methane emissions, and greenhouse gas emissions. These indicators are published by the World Bank. In this study, these indicators are constructed in the form of new environmental index using the principal component analysis (PCA) method. The formulation and description of the new environmental index is described in Section 2, Research Method. To the best of our knowledge, the analysis of new index of the environment using PCA is largely ignored by previous studies and therefore, this will be a significant contribution to the literature of EKC.

The literature has widely estimated EKC at both country and cross-country levels. For example, Lin et al. (2016) estimated the EKC for five African countries during 1980-2010 using the STIRPAT empirical model, panel cointegration, and fully modified ordinary least squares. They found that there was no evidence of EKC as a reference for environmental policies in Africa. EKC study in a more specific area was carried out by Fujii et al. (2018) using a sample of 276 cities in 26 countries for 2000, 2005, and 2008. They found that EKC happened in 276 cities indicated by an inverted U-shaped relationship between CO_2 emissions and urban economic growth. An interesting finding was yielded by Lawson et al. (2020) that no evidence of EKC was found at the global level so that international agreements are not effective in executing reductions in CO_2 emission levels, especially in high-income countries. Therefore, this current study estimates EKC in developing countries following the basic EKC model applied by Ali et al. (2020) and several empirical studies as references for determining explanatory variables, such as GDP per capita, trade openness, foreign direct investment (FDI), institutions, and globalization (Castiglione, Infante & Smirnova, 2012; Lin et al., 2016; Egbetokun, Osabuohien, & Akinbobola, 2018; Lau, Choong & Ng, 2018; Fujii et al., 2018; Jiang et al., 2019; Churchill et al., 2020; Boubellouta & Kusch-Brandt, 2020; Chen & Taylor, 2020; Halliru et al., 2020; Sarkodie & Ozturk, 2020; Suki et al., 2020; and Yameogo et al., 2021).

The current study aims to estimate the EKC hypothesis for 97 developing countries during 1991-2014. The year of 1991 is the beginning period of the study, following the beginning of an empirical study on the application of EKC, while 97 developing countries are set to follow the World Bank's publication of environmental indicators used in forming new environment index. This study also narrows the estimation period during 1996-2014 to value the significant contribution of institutions to EKC. The year of 1996 is the year of the first publication of governance indicators in the worldwide governance indicators (WGI) by the World Bank. WGI contains six institutional indicators, including voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, and control of corruption. These institutional indicators will be constructed into new index of institutions using the principal component analysis (PCA) method. Moreover, the new index of institutions will serve as significant contributions to the EKC literature.

In particular, the EKC analysis also involves the significant contribution of institutions as one of the important indicators in developing countries. In general, the literature argues that the quality level of institutions in developing countries is relatively low. The findings of the contribution of institutions in the EKC show that the rule of law has negative implications for the environment in European countries (Castiglione, Infante & Smirnova, 2012). Lau, Choong & Ng (2018) estimated EKC in 100 developed and developing countries, that control of corruption contributes dominantly in reducing CO_2 emission levels in high-income countries, while the rule of

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law provides benefits to the environment except in low-income countries. Studies in developing countries such as African countries indicate that policymakers should improve the quality of institutions, especially in Southern Africa, to support environmental policies following the EKC concept (Egbetokun, Osabuohien, & Akinbobola, 2018). These findings have encouraged the current study to propose new indexes of institutions as new contributions to the EKC analysis in developing countries.

This study will fill the empirical gap in the EKC literature in several ways. First, this study constructs new index of the environment using the PCA method. The new index are composite indexes that combine several environmental indicators that have been used by previous studies. Second, this study constructs new index of institutions using PCA, contributes to literature of EKC following previous empirical studies. The assessment of the new index of institutions is carried out with composite indexes of six governance indicators. In addition, the new index of institutions is also fresh series of evidence for the estimation of the EKC empirical model. Third, the empirical estimation model using non-linear static panels includes quadratic and cubic regressions. Furthermore, robustness checks are performed using non-linear dynamic panels, consisting of quadratic and cubic regressions. Fourth, this study uses a large number of data from around 97 developing countries in 1991-2014 that experienced increasing levels of both CO2 and greenhouse gas emissions, according to the publication of the World Bank. Finally, the findings of the study have implications for environmental policies, such as policies for controlling and reducing the impact of increasing emissions within the framework of environmental sustainability, improving the quality of institutions in developing countries, anticipating and mitigating external economic impacts such as trade openness, globalization, and FDI inflows on the quality of the domestic environment.

This study is structured following the organization. Section 1 describes the introduction. Section 2 depicts the research method. Section 3 explores the results and discussion. Section 4 is the conclusion.

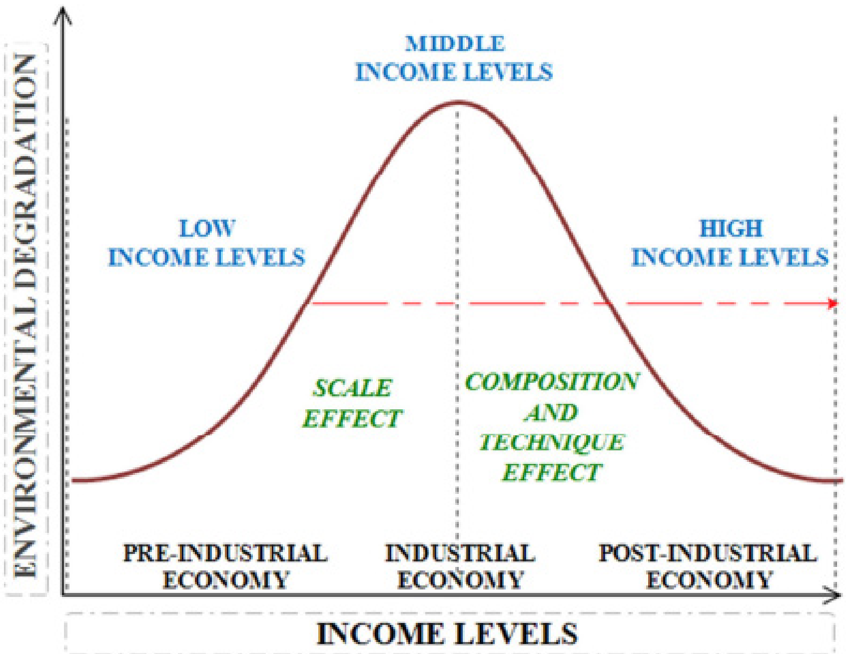

Figure 1. Inverted U-Shaped of EKC Hypothesis

Source: Sarkodie & Strezov (2018)

2. RESEARCH METHOD

2.1 New Indexes of Environment and Institutions

This study proposes two new indexes in the EKC analysis in developing countries, including the environmental quality index and the institutional quality index. Most of the literature in EKG has missed out on the estimation of the environmental and institutional composite indexes. The compilation of the composite indexes is a breakthrough for EKC analysis to deepen the proof of the U-shaped or inverted U-shaped relationship. One method that can measure the composite indexes is principal component analysis (Jollife, 2002; and Gniazdowski, 2017).

Principal component analysis (PCA) is a method for reducing the dimensionality level of a large number of interrelated data (Jollife, 2002) and following a geometric approach (Gniazdowski, 2017). This study employs eight dimensions of environmental indicators published by the World Bank to measure the environmental quality index in 97 developing countries for the years 1991-2014, covering CO_2 emission of transport, CO_2 emission of other sectors, CO_2 emission of manufacturing industries and construction, CO_2 emission of electricity and heat production, CO_2 emission of residential buildings and commercial and public services, nitrous oxide emissions (N_2O), methane emissions (CH_4), and greenhouse gas emissions (GHG). The PCA formulation of the new environmental quality (EI) index is as follows:

$$EI = \frac{1}{2}\left[\frac{\sqrt{CO2_k^2 + CH4_k^2 + N2O_k^2 + GHG_k^2}}{\sqrt{n}} + \left(1 - \frac{\sqrt{(z - CO2_k)^2 + (z - CH4_k)^2 + (z - N2O_k)^2 + (z - GHG_k)^2}}{\sqrt{n}}\right)\right] \quad (1)$$

Where z denotes the weight of wi, which is determined intrinsically. CO_2 is the dimension of CO_2 emission, while CH_4, N_2O, and GHG describe the dimensions of methane emission, nitrous oxide emission, and greenhouse gas emission, respectively. Meanwhile, n is the number of observations. A detailed description of the environmental quality index can be seen in Table 1.

Furthermore, the PCA formulation for the new indexes of institutional quality (IQ) consists of six governance indicators published in the worldwide governance indicator (WGI). The measurement of the institutional quality indexes is carried out on 97 developing countries during 1996-2014. In simple terms, the PCA equation for the new indexes of institutional quality (IQ) is as follows:

$$IQ = \frac{1}{2}\left[\frac{\sqrt{VA_k^2 + PSAV_k^2 + GE_k^2 + RQ_k^2 + RL_k^2 + CC_k^2}}{\sqrt{n}} + \left(1 - \frac{\sqrt{(z - VA_k)^2 + (z - PSAV_k)^2 + (z - GE_k)^2 + (z - RQ_k)^2 + (z - RL_k)^2 + (z - CC_k)^2}}{\sqrt{n}}\right)\right] \quad (2)$$

Where VA denotes voice and accountability, PSAV equals political stability and absence of violence, GE is government effectiveness, RQ is regulatory quality, RL represents rule of law, and CC equals control of corruption. A complete description of the environmental quality index can be seen in Table 1.

2.2 Econometrics Techniques

This study aims to estimate the EKC following the general equation employed by Ali et al. (2020) that environmental quality (EI) indicators are determined by Gross Domestic Product (GDP) as follows:

$$EI = a_0 + a_1 GDP + a_2 GDP^2 + \mu \quad (3)$$

Equation (3) can be made in more detailed to demonstrate a more specific form of the function, where (a) $a_1=a_2=0$ denotes no growth-pollution relationship, (b) $a_1>0$ and $a_2=0$ equal linearly increasing growth-pollution relationship , (c) $a_1<0$

and a_2=0 represent linearly decreasing growth-pollution relationship, (d) a_1>0 and a_2<0 denote inverted U-shaped growth-pollution relationship, and (e) a_1<0 and a_2>0 are U-shaped/monotonically increasing growth-pollution relationship. Specifically, this study uses GDP per capita following the literature that extensively examines EKC.

Furthermore, Equation (3) can be rewritten in the form of equations for static panel quadratic regression (Equation 4) and cubic regression (Equation 5), by adding several explanatory variables following the literature. The literature has determined that the explanatory variables (X) that are widely applied in the empirical analysis of EKC are trade openness, foreign direct investment (FDI), institutional quality, and globalization. Therefore, this study will estimate two static panel models as follows:

$$EI_{it} = a_0 + a_1 GDP_{it} + a_2 GDP_{it}^2 + a_3 \sum_k^1 X_{it} + \mu_{it} \quad (4)$$

Where *t* is 1991-2014 for environmental quality index and 1996-2014 for institutional quality index. The *i* represents 97 developing countries. Moreover, the time period of environmental quality index will be utilized to address the Model 1 and 2 (Table 2 and 3). Meanwhile, the time period of institutional quality index will be applied to address Model 3 and 4. The different setting of time period will lead a different number of observations.

$$EI_{it} = a_0 + a_1 GDP_{it} + a_2 GDP_{it}^2 + a_3 GDP_{it}^3 + a_4 \sum_k^1 X_{it} + \mu_{it} \quad (5)$$

This study also estimates Equation (3) using a dynamic panel model to obtain a robustness check of EKC analysis in developing countries. Dynamic panel regression can be explained by the difference generalized method of moment (GMM). Conceptually, the difference GMM was proposed by Arellano and Bond (1991). In simple terms, Equations (4) and (5) can be rewritten in the form of dynamic panel regression as follows:

$$EI_{it} = \beta_0 + \beta_1 EI_{it-1} + \beta_2 GDP_{it} + \beta_3 GDP_{it}^2 + \beta_4 \sum_k^1 X_{it} + \mu_{it} \quad (6)$$

$$EI_{it} = \beta_0 + \beta_1 EI_{it-1} + \beta_2 GDP_{it} + \beta_3 GDP_{it}^2 + \beta_4 GDP_{it}^3 + \beta_5 \sum_k^1 X_{it} + \mu_{it} \quad (7)$$

2.3 Data

The study determines the environmental quality indexes as the dependent variables and GDP per capita as the independent variable, following the EKC literature. A total of 97 developing countries during the period 1991-2014 are selected as the research samples, following the publication of the World Bank on environmental indicators and indications that developing countries are at risk of increasing CO_2 emissions. Table 1 presents that the environmental quality indexes in developing countries tend to be heterogeneous between countries and have the trend to increase. It can be seen from the minimum and maximum values of -2.30 and 7.15, respectively. The same trends happen at the level of GDP per capita, where the difference in GDP per capita is relatively large among countries, with the minimum and maximum values of USD437 and USD106,104, respectively. Table 1 also provides a statistical description of several explanatory variables, such as the institutional quality index, trade openness, globalization index, and foreign direct investment (FDI) inflows.

In particular, the institutional quality indexes, as the results of the PCA measurement, have a relatively significant difference of the lowest and highest values, which are -3.23 and 3.63, respectively. When a country has a negative level of institutional quality, the country is facing a problem with a fairly low level of institutional quality. On the other hand, when a country has a better (positive) level of institutional quality, the country can encourage institutional quality improvement.

Moreover, 97 developing countries researched in this study are Albania, Algeria, Angola, Argentina, Armenia, Azerbaijan, Bahrain, Bangladesh, Belarus, Benin, Bolivia, Botswana, Brazil, Brunei Darussalam, Cambodia, Cameroon, Chile, China, Colombia, Congo Dem. Rep., Congo Rep., Costa Rica, Cote d'Ivoire, Cyprus, Czech Republic, Dominican Republic, Ecuador, Egypt Arab Rep., El Salvador, Ethiopia, Gabon, Ghana, Guatemala, Haiti, Honduras, Hong Kong SAR, India, Indonesia, Iran Islamic Rep., Iraq, Israel, Jamaica, Jordan, Kazakhstan, Kenya, Korea Rep., Kuwait, Kyrgyz Republic, Latvia, Lebanon, Libya, Lithuania, Malaysia, Malta, Mauritius, Mexico, Moldova, Mongolia, Morocco, Mozambique, Myanmar, Namibia, Nepal, Nicaragua, Nigeria, Oman, Pakistan, Paraguay, Peru, Philippines, Qatar, Saudi Arabia, Senegal, Serbia, Singapore, Slovak Republic, Slovenia, South Africa, Sri Lanka, Sudan, Syrian Arab Republic, Tajikistan, Tanzania, Thailand, Togo, Tunisia, Turkey, Turkmenistan, Ukraine, United Arab Emirates, Uruguay, Uzbekistan, Venezuela, Vietnam, Yemen Rep., Zambia, and Zimbabwe.

Table 1. Descriptive Statistics

Variables	Description	Unit of Measurement	Source	Mean	Std. Dev.	Min.	Max.
Environmental Index (ei)	A new index of environmental quality is assessed using PCA that covers CO_2 emissions (such as transport, other sectors, manufacturing industries and construction, electricity and heat production, residential buildings and commercial and public services), nitrous oxide emissions, methane emissions, and greenhouse gas emissions.	A negative value equals a high quality of environment, while a positive value equals a low quality of environment.	The World Bank and the authors' calculation	0.01	0.96	-2.38	7.15
GDP per Capita (gdpc)	GDP per capita is the constant price of 2017 (USD).	USD	The World Bank	13,745	17,217	437	106,104
Institutional Quality Index (iq)	It is a new index of institutional quality. It is assessed using PCA that covers six indicators of governance, including voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, and control of corruption.	A negative value equals a low quality of institutions, while a positive value equals a high quality of institutions.	The World Bank and the authors' calculation	0.01	1.15	-3.23	3.63
Trade Openness (to)	Sum of export and import to GDP ratio.	%	The World Bank	84.28	54.97	0.02	442.62
FDI Inflows to GDP ratio (fdi)	FDI Inflows to GDP ratio.	%	The World Bank	4.85	18.80	-11.14	449.08

Variables	Description	Unit of Measurement	Source	Mean	Std. Dev.	Min.	Max.
Globalization Index (gi)	The KOF index measures the economic, social and political dimensions of globalization. The score of each country is given out of 100, the higher score indicates “more globalized”, while the lower score equals “less globalized”.	An index	KOF Globalization Index	56.66	11.91	22.77	85.34

3. Results and Discussion

3.1 The Main Results

This study estimates Equations (4) and (5) following the EKC concept in literature. The majority of empirical studies have valued EKC in quadratic regression. This study expands the estimation to cubic regression to clarify and deepen the findings of non-linear EKC in 97 developing countries. The main findings of the study demonstrate that EKC is in the form of a U-shaped relationship in static panel estimation without institutions and globalization. On the other hand, EKC shows an inverted U-shaped relationship when the static panel estimate considers institutions and globalization.

Table 2 exhibits the results of non-linear static panel estimation of EKC analysis in developing countries during 1991-2014. This table provides an understanding that the EKC hypothesis can be proven globally following the dynamics of environmental, economic, and institutional indicators, especially in each country. For example, the more open the economy in developing countries is, the more indications of an increase in economic activity followed by an increase in environmental pollution will be. This means that economic development and economic openness in developing countries tend not to be followed by policies to control environmental impacts.

Static panel-OLS estimation results prove that EKC demonstrates a U-shaped relationship supported by a significant contribution of trade openness (Model 2). An increase in trade openness indicates that the risk of environmental degradation also increases. In addition, Model 4 emphasizes two important findings, namely: (a) EKC shows an inverted U-shaped relationship, and (b) FDI inflows and globalization have significant and positive implications, while institutional quality has significant and negative implications. This implies that policymakers in developing countries should pay more attention to the improvement of the quality of institutions and pro-green growth policies towards economic openness and foreign investment.

Fixed effect and random effect estimation also presents consistent findings that EKC demonstrates a U-shaped relationship in static panel regression without institutions and globalization, while EKC shows an inverted U-shaped relationship in static panel regression with institutions and globalization. Thus, this study has been able to provide new evidence for EKC in developing countries by emphasizing the significant contribution of institutions.

However, the static panel estimation results show weakness in demonstrating the goodness of fit indicated by the R-square value. The R-square value is very poor as an indication that the specification of the static panel model cannot generalize the findings of the EKC in developing countries during 1991-2014. The goodness of fit for static panel regression should be improved with other approaches, such as dynamic panel regression. Therefore, this study estimates Equations (6) and (7), following the difference generalized method of moment (GMM) concept. Conceptually, the difference GMM was proposed by Arellano and Bond (1991).

Table 2. Non-linear Static Panel Results

Variables	Pooled OLS				Fixed Effects			
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Constant	-0.288 (3.30)***	-0.369 (-4.01)***	-0.863 (-6.27)***	-0.848 (-6.09)***	-0.377 (-8,54)***	-0.463 (-8.79)***	-0.999 (-8.83)***	-0.982 (-8.54)***
GDPC	1.660e-5 (3.84)***	3.380e-5 (4.55)***	-4.05e-06 (-1.33)	-7.63e-06 (-1.41)	2.390e-5 (5,32)***	4.260e-5 (5.51)***	-4.78e-06 (-1.55)	-8.75e-06 (-1.60)
GDPC2	-6.97e-11 (-1.47)	-6.91e-10 (-3.09)***	5.82e-11 (1.70)*	1.79e-10 (1.15)	-1.260e-10 (-2.58)**	-8.04e-10 (-3.45)***	6.51e-11 (1.88)*	2.00e-10 (1.27)
TO	0.001 (2.60)**	0.002 (3.00)***	6.208e-4 (1.59)	6.082e-4 (1.55)	0.002 (2.99)***	0.002 (3.39)***	6.956e-4 (1.75)*	6.831e-4 (1.72)*
FDI	-2.59e-4 (-0.37)	1.696e-4 (-0.24)	0.001 (2.25)**	0.001 (2.23)**	-2.723e-4 (-0.39)	-1.670e-4 (-0.24)	0.001 (2.09)*	0.003 (2.06)**
GDPC3		4.61e-15 (2.84)**		-9.11e-16 (-0.80)		5.01e-15 (2.97)***		-1.01e-15 (-0.88)
IQ			-0.050 (-2.57)**	-0.050 (-2.55)**			-0.034 (-1.67)*	-0.033 (-1.66)*
GI			0.015 (7.72)***	0.015 (7.74)***			0.017 (8.76)***	0.017 (8.76)***
R-square	0.03	0.04	0.03	0.03	0.03	0.04	0.03	0.03
Constant	-0.288 (-3.30)***	-0.370 (-4.01)***	-0.863 (-6.27)***	-0.848 (-6.09)***				
GDPC	1.660e-5 (3.84)***	3.380e-5 (4.55)***	-4.05e-06 (-1.33)	-7.63e-06 (-1.41)				
GDPC2	-6.97e-11 (-1.47)	-6.91e-10 (-3.09)***	5.82e-11 (1.70)*	1.79e-10 (1.15)				
TO	0.001 (2.60)**	0.002 (3.00)***	6.208e-4 (1.59)	6.082e-4 (1.55)				
FDI	-0.001 (-0.37)	-1.696e-4 (-0.24)	0.001 (2.25)**	0.001 (2.23)**				
GDPC3		4.61e-15 (2.84)**		-9.11e-16 (-0.80)				
IQ			-0.050 (-2.57)**	-0.041 (-2.55)**				
GI			0.015 (7.72)***	0.015 (7.74)***				
R-square	0.03	0.04	0.03	0.03				
Observations	2328	2328	1843	1843	2328	2328	1843	1843

Source: The Authors' calculation

Note: t-statistics is in the parenthesis (). ***, ** and * denote significant level at 1%, 5% and 10%, respectively. The Hausman tests of Model 1, 2, 3 and 4 are 54.33***, 22.88***, 140.72***, and 109.63***, respectively. Dependent variable is environmental quality index (EI).

Table 3. Non-linear Dynamic Panel Results

Variables	Pooled OLS				Fixed Effect			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Constant					0.058 (3.04)***	0.104 (3.50)***	0.065 (0.69)	0.084 (0.89)
EI(-1)	0.863 (80.96)***	0.859 (79.55)***	0.832 (61.84)***	0.833 (61.79)***	0.862 (79.68)***	0.834 (62.03)***	0.835 (62.04)***	0.835 (61.97)***
GDPC	-3.100e-6 (-1.84)*	6.190e-6 (1.76)*	-7.550e-6 (-3.42)***	-1.030e-5 (-2.68)**	-4.590e-6 (-2.59)**	-1.130e-5 (-2.84)**	-7.660e-6 (-3.41)***	-1.120e-5 (-2.81)**
GDPC2	3.190e-11 (1.57)	-3.670e-10 (-2.74)**	7.480e-11 (2.89)**	1.730e-10 (1.49)	4.960e-11 (2.34)**	2.040e-10 (1.72)*	7.560e-11 (2.89)**	2.000e-10 (1.68)*
GDPC3		3.390e-15 (3.01)***		-7.690e-16 (-0.87)		-1.010e-15 (-1.12)		-9.710e-16 (-1.08)
TO	1.890e-4 (1.03)	2.150e-5 (0.11)	-4.420e-6 (-0.02)	-4.090e-5 (-0.16)	-1.780e-4 (-0.87)	-8.790e-5 (-0.34)	-2.990e-5 (-0.12)	-7.920e-5 (-0.31)
FDI	-2.690e-4 (-0.48)	-1.410e-4 (-0.25)	-3.960e-5 (-0.06)	-2.50e-5 (-0.04)	-3.590e-5 (-0.66)	-8.430e-5 (-0.13)	-5.970e-5 (-0.09)	-4.550e-5 (-0.07)
IQ			-0.017 (-1.52)	-0.018 (-1.59)			-0.010 (-0.68)	-0.009 (-0.62)
GI			0.001 (3.48)***	0.002 (3.35)***			3.350e-4 (0.21)	3.270e-4 (0.21)
Adj. R-square	0.75	0.75	0.71	0.71	0.78	0.71	0.71	0.71
Constant	0.058 (1.74)*	0.071 (1.98)*	0.053 (0.67)	0.069 (0.86)				
EI(-)	0.862 (80.04)***	0.861 (79.82)***	0.833 (61.95)***	0.832 (61.87)***				
GDPC	-4.660e-6 (-2.64)**	-7.250e-6 (-2.37)**	-7.850e-6 (-3.49)***	-1.120e-5 (-2.82)**				
GDPC2	5.040e-11 (2.38)**	1.460e-10 (1.55)	7.780e-11 (2.97)**	1.960e-10 (1.66)*				
GDPC3		-7.670e-16 (-1.04)		-9.240e-16 (-1.03)				
TO	-1.740e-4 (-0.85)	-2.130e-4 (-1.02)	-1.390e-5 (-0.05)	-6.080e-5 (-0.23)				
FDI	-3.320e-4 (-0.61)	-3.300e-4 (-0.61)	-4.340e-5 (-0.07)	-2.710e-5 (-0.04)				
IQ			-0.012 (-0.92)	-0.012 (-0.88)				
GI			5.420e-4 (0.41)	0.001 (0.44)				
R-square	0.76	0.76	0.71	0.71				
Observations	2231	2231	1746	1746	2231	1746	1746	1746

Source: The Authors' calculation

Note: t-statistics is in the parenthesis (). ***, ** and * denote significant level at 1%, 5% and 10%, respectively. Dependent variable is Environmental Quality Index (EI).

3.2 Robustness Checks

The dynamic panel of EKC is estimated following Equations (6) and (7). The general findings show that EKC takes the form of an inverted U-shaped relationship in developing countries but the contribution of institutions is not proven. However, the goodness of fit (Adjusted R-square) shows a relatively precise level, which is above 70%. This finding signalizes that the dynamic estimation model is appropriate to prove the inverted U-shaped relationship of EKC but cannot provide new evidence for the significant contribution of institutions in developing countries.

Dynamic panel-OLS can demonstrate that Models 1, 3, and 4 have an inverted U-shaped relationship, while Model 2 shows a U-shaped relationship. Empirical findings also show consistent results of significant dynamic panel effects for all estimation models. This confirms that there is a non-linear and dynamic relationship between the environmental quality index and GDP per capita in developing countries during 1991-2014. The findings of this study are supported by Fujii et al. (2018). In contrast, the findings of this study are not promoted by Lin et al. (2016) and Lawson et al. (2020). Besides, the new environmental quality index following the PCA method is appropriate to address the study objective. Most previous study on EKC and institutions largely ignore to construct new index following the PCA method. Thus, the current study present new evidence and significant contribution the existing literature.

Furthermore, the findings of dynamic fixed effects and random effects also provide two insights. First, all estimation models are dynamic panel regressions which are explained by the significance of the impact of the lagged dependent variable (EI(-1)) on the environmental quality indexes in developing countries in the periods of 1991-2014 and 1996-2014. The time period of 1991-2014 is utilized to estimate the Model 1 and 2 (Table 2 and 3). In contrast, the time period of 1996-2014 is applied to estimate the Model 3 and 4. Second, EKC demonstrates an inverted U-shaped relationship as found in the literature. Otherwise. Dynamic panel regression cannot explain the significant evidence of the impact of institutions and economic openness in the EKC model in developing countries. In general, the low level of economic openness in developing countries can be a driving factor for the inability of global markets and investment to affect the level of environmental quality following dynamic estimation models.

3.3 Discussion

Much of the EKC literature argues that the environmental quality and GDP per capita show an inverted U-shaped relationship. The current study has found that the inverted U-shaped relationship can be proven in developing countries following the panel dynamic regression model. Further, the static panel regression model by setting institutions as a determinant also gives the result that EKC demonstrates an inverted U-shaped relationship. New empirical evidence that can be proven in this study is the measurement of environmental quality indexes and institutions following the principal component analysis (PCA) method.

Developing countries are relatively supported by the availability of natural resources. This suggests that domestic economic activity will be encouraged by the readiness of natural resources and the dynamics of environmental quality as found by Badeeb et al. (2020) in Malaysia in 1970-2016, that natural resources contributed significantly to the proof of EKC validity. In addition, if developing countries are increasingly active in advancing their economy to a global level with the consequence that an increase in economic openness, foreign investment, and globalization can occur, there are indications that the dynamics of the global economy have an impact on the quality of the environment in each developing country. This phenomenon has been described in this study, following the estimation results of static panel regression supported by previous empirical studies. For example, several studies that have found a significant impact of trade openness, FDI, and globalization in the EKC model include Jiang et al. (2019), Chen & Taylor (2020), Churchill et al. (2020), Haliru et al. (2020), Suki et al. (2020), and Yameogo et al.

(2021).

The findings of this study also confirm the significant impacts of institutions on the ECK model following a non-linear static panel regression model. Limited literature has paid more attention to and discussed the significant contribution of institutions to EKC. For example, Castiglione, Infante & Smirnova (2012) have mentioned that institutional indicators such as the rule of law play a significant role in the ECK model so that policymakers should improve the quality of institutions to control negative environmental impacts. Another study has found that institutions have significant implications for the EKC model as explored by Egbetokun, Osabuohien & Akinbobola (2018) in North and Southern Africa, and Lau, et al. (2018) in 100 countries. The latest study has also provided the same finding that institutions are one of the significant indicators in the EKC model in Sub-Saharan African countries (Yameogo et al., 2021).

4. Conclusion

Increasing levels of CO_2 emissions in developing countries can be investigated thoroughly following the concept of the Environmental Kuznets Curve (EKC) Hypothesis. The current study intends to estimate EKC with several empirical models including static and dynamic panels with quadratic and cubic regressions on a traditional EKC for 97 developing countries in 1991-2014. Further, the estimation of EKC under institutions takes the advantage of static and dynamic panels with quadratic and cubic regressions for 97 countries during 1996-2014. The novel evidence for EKC estimation is emphasized on the new indexes of the environment and institutions following the principal component analysis method.

The findings of this study express that an inverted U-shaped relationship can occur when the EKC estimation is carried out through dynamic panels, with and without institutions. In addition, the static panel with institutions also shows that the EKC is inverted U-shaped. This outcome provides several insights: EKC in developing countries is non-linear and inverted U-shaped, following dynamic estimation; institutions contribute significantly to the proving that EKC is inverted U-shaped; and external economy can determine the level of CO2 emissions.

The policy implications direct policymakers to adopt climate change mitigation within the framework of environmental sustainability, improve the quality of institutions in developing countries, and manage anticipatory macroeconomy against external shocks, such as openness, globalization, and FDI inflows. This signifies that the environmental policy under the concept of EKC cannot be separated from the quality of institutions and the dynamics of the global economy.

5. References

Badeeb, R. A., Lean, H. H. & Shahbaz, M. (2020). Are too many natural resources to blame for the shape of the Environmental Kuznets Curve in resource-based economies? *Resources Policy, 68,* 101694. https://doi.org/10.1016/j.resourpol.2020.101694

Boubellouta, B., & Kusch-Brandt, S. (2020). Testing the environmental Kuznets Curve hypothesis for E-waste in the EU28+2 countries. *Journal of Cleaner Production*, *277*, 123371. https://doi.org/10.1016/j.jclepro.2020.123371

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

Chen, Q., & Taylor, D. (2020). Economic development and pollution emissions in Singapore : Evidence in support of the Environmental Kuznets Curve hypothesis and its implications for regional sustainability. *Journal of Cleaner Production*, *243*, 118637. https://doi.org/10.1016/j.jclepro.2019.118637

Chen, X., Huang, B., & Lin, C. Te. (2019). Environmental awareness and environmental Kuznets curve. *Economic Modelling*, *77*(September), 2–11. https://doi.org/10.1016/j.econmod.2019.02.003

Churchill, S. A., Inekwe, J., Ivanovski, K., &

Smyth, R. (2018). The Environmental Kuznets Curve in the OECD: 1870–2014. *Energy Economics*, *75*, 389–399. https://doi.org/10.1016/j.eneco.2018.09.004

Churchill, S. A., Inekwe, J., Ivanovski, K., & Smyth, R. (2020). The Environmental Kuznets Curve across Australian states and territories. *Energy Economics*, *90*, 104869. https://doi.org/10.1016/j.eneco.2020.104869

Egbetokun, S., Osabuohien, E. S. & Akinbobola, T. (2018). Feasible Environmental Kuznets and Institutional Quality in North and Southern African Sub-regions. *International Journal of Energy Economics and Policy, 8(1),* 104-115.

Fujii, H., Iwata, K., Chapman, A., Kagawa, S., & Managi, S. (2018). An analysis of urban environmental Kuznets curve of CO2 emissions: Empirical analysis of 276 global metropolitan areas. *Applied Energy*, *228*(May), 1561–1568. https://doi.org/10.1016/j.apenergy.2018.06.158

Gniazdowski, Z. (2017). New Interpretation of Principal Components Analysis. *Zeszyty Naukowe WWSI*, *16, 11,* 43-65.

Halliru, A.M, Loganathan, N., Hassan, A.A.G., Mardani, A. & Kamyab, H. (2020) Reexamining the environmental Kuznets curve hypothesis in the Economic Community of West African States: A panel quantile regression approach. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2020.124247.

Jiang, L., He, S., Zhong, Z., Zhou, H. & He, L. (2019). Revisiting environmental kuznets curve for carbon dioxide emissions: The role of trade. *Structural Change and Economic Dynamics, 50,* 245-257. https://doi.org/10.1016/j.strueco.2019.07.004

Jollife, I.T. (2002). Principal Component Analysis. Second Edition. New York: Springer-Verlag.

Lau, L.-S., Choong, C.-K., & Ng, C.-F. (2018) Role of Institutional Quality on Environmental Kuznets Curve: A Comparative Study in Developed and Developing Countries. *Advances in Pacific Basin Business, Economics and Finance*; 223-247. https://doi.org/10.1108/S2514-465020180000006007

Lawson, L. A., Martino, R., & Nguyen-Van, P. (2020). Environmental convergence and environmental Kuznets curve: A unified empirical framework. *Ecological Modelling*, *437*(September), 109289. https://doi.org/10.1016/j.ecolmodel.2020.109289

Lin, B., Omoju, O. E., Nwakeze, N. M., Okonkwo, J. U., & Megbowon, E. T. (2016). Is the environmental Kuznets curve hypothesis a sound basis for environmental policy in Africa? *Journal of Cleaner Production*, *133*, 712–724. https://doi.org/10.1016/j.jclepro.2016.05.173

Sarkodie, S. A., & Strezov, V. (2018). Empirical study of the Environmental Kuznets curve and Environmental Sustainability curve hypothesis for Australia, China, Ghana and USA. *Journal of Cleaner Production*, *201*, 98–110. https://doi.org/10.1016/j.jclepro.2018.08.039

Sarkodie, S. A. & Ozturk, I. (2020). Investigating the Environmental Kuznets Curve hypothesis in Kenya: A multivariate analysis. *Renewable and Sustainable Energy reviews, 117,* 109481. https://doi.org/10.1016/j.rser.2019.109481

Suki, N. M., Sharif, A., Afshan, S. & Suki, N. M. (2020). Revisiting the Environmental Kuznets Curve in Malaysia: The role of globalization in sustainable environment. *Journal of Cleaner Production, 264,* 121669. https://doi.org/10.1016/j.jclepro.2020.121669

Yameogo, C.E.W., Omojolaibi, J.A. & Dauda, R.O.S. (2021). Economic globalisation, institutions and environmental quality in Sub-Saharan Africa. *Research in Globalization, 3,* 100035. https://doi.org/10.1016/j.resglo.2020.100035