Testing the Validation of Environmental Kuznets Curve Hypothesis for sustainable Green Economic Growth in Africa

اختبار التحقق من صحة فرضية منحنى كوزنتس البيئي من أجل النمو الاقتصادي الأخضر المستدام في أفريقيا

مروة عادل الحسنين

أستاذ مساعد بكلية الدراسات الإفريقية العليا – جامعة القاهرة

Abstract

This paper aimed at testing the Environmental Kuznets Curve (EKC) Hypothesis in 48 African countries as a whole and as divided into four groups by the World Bank classification. Also, calculating turning points and turning years in groups where the EKC hypothesis is accepted.

This paper collected data from World Development Indicators (WDI), over the period of 1990–2019. It used the methods of panel data and time-series analysis. As for panel data analysis, the study used stationary of panel data, cointegration tests for panel data, estimation of panel data models, and estimation of long-run parameters using panel D-OLS. Regarding time time-series data analysis, the study depended on stationary of time series data, cointegration test for time-series data, and estimation of long-run parameters using D- OLS. For both analyses, the study applied Granger causality test, and estimation of turning points and turning years.

Results reveled that in the whole Africa and two groups (African upper middle-income countries, and African high-income countries) elaborated environmental Kuznets curve hypothesis.

This paper has not only tested the validation of (EKC) scheme, but also it calculated the turning points and turning years in the groups which the hypothesis was applicable.

Keywords Africa, cointegration tests, Environmental Kuznets Curve (EKC), Granger causality test, Panel data

المستخلص

تهدف هذه الورقة إلى اختبار فرضية منحنى كوزنتس البيئي (EKC) في ٤٨ دولة أفريقية ككل ومقسمة إلى أربع مجموعات حسب تصنيف البنك الدولي. وكذلك حساب نقاط التحول وسنوات التحول في المجموعات التي يتم قبول فرضية EKC فيها.

جمعت هذه الورقة بيانات من مؤشرات التنمية العالمية(WDI) ، خلال الفترة ١٩٩٠–٢٠١٩. واستخدمت أساليب بيانات اللوحة وتحليل السلاسل الزمنية. أما بالنسبة لتحليل بيانات اللوحة، فقد استخدمت الدراسة بيانات اللوحة الثابتة،

واختبارات التكامل المشترك لبيانات اللوحة، وتقدير نماذج بيانات اللوحة، وتقدير المعلمات طويلة المدى باستخدام لوحة .D–OLS وفيما يتعلق بتحليل بيانات السلاسل الزمنية، اعتمدت الدراسة على بيانات السلاسل الزمنية الثابتة، واختبار التكامل المشترك لبيانات السلاسل الزمنية، وتقدير المعلمات طويلة المدى باستخدام .D–OLS وفي كلا التحليلين، طبقت الدراسة اختبار السببية جرانجر، وتقدير نقاط التحول وسنوات التحول.

وكشفت النتائج أنه في أفريقيا بأكملها ومجموعتين (البلدان الأفريقية ذات الدخل المتوسط الأعلى، والبلدان الأفريقية ذات الدخل المرتفع) وضعت فرضية منحنى كوزنتس البيئي.

لم يختبر هذا البحث التحقق من صحة مخطط (EKC) فحسب، بل قام أيضًا بحساب نقاط التحول وسنوات التحول في المجموعات التي تنطبق عليها الفرضية.

الكلمات المفتاحية: أفريقيا، اختبارات التكامل المشترك، منحنى كوزنتس البيئي(EKC) ، اختبار السببية جرانجر، بيانات اللوحة

1. Introduction

OECD defines green growth as “fostering economic growth and development, while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies”. (OECD, 2022)

Green growth is necessary because risks to development are rising as growth continues to erode natural capital. The green economy aims to achieve economic growth and development without an adverse impact on the environment. A green economy is characterized by low carbon emissions, resource efficiency and social inclusiveness. A green economy stimulates growth and employment through increased public and private investments in renewable energy, which is a strategic policy choice that would contribute to a competitive, innovative environmental sustainability. (Adamowicz, 2022)

The environmental Kuznets curve (EKC) hypothesis explains the relationship between economic activity and environmental degradation. Therefore, environmental conservation policies, technological advancement and modern industrial policies are required to make the economic growth of the countries more effective in reducing CO_2 emissions. (Jebli *et al*., 2022)

So, there is a need for green growth by the tools of environmental sustainability because risks to development are rising as growth continues to erode natural capital. Therefore, understanding the relation between CO_2 emissions and economic growth through environmental Kuznets curve helps economies in formulating energy policies and developing energy resources in sustainable ways.

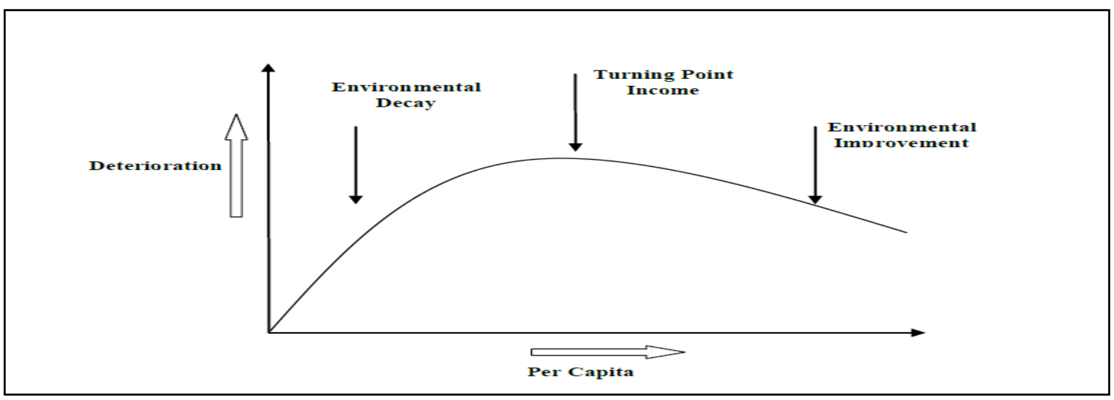
2. Theoretical background of Environmental Kuznets Curve

The environmental patterns have been called Environmental Kuznets Curve (EKC) due to the similarity with the relationship between the level of inequality and per capita income considered by (Kuznets, 1955) in his paper entitled "Economic Growth and Income Inequality".

The Environmental Kuznets Curve (EKC) provides an analytical framework to examine how economies deal with environmental issues. The EKC hypothesis has been the dominant theory explaining the link between economic growth and environmental degradation since the early 1990s with path breaking study of the potential impacts of NAFTA (Grossman and Krueger 1991). They tested the validity of the EKC hypothesis and found that there was an inverse-U-shaped relationship between economic growth usually measured in terms of income per capita, and environmental degradation, measured by environmental indicators such as per capita CO_2 emission.

In the early stages of economic growth, environmental degradation and pollution increase, with an increase in per capita income, economic growth leads to environmental improvement. It states that the environment begins to improve with the growth of GDP per capita. That happens when a rise in per capita income passes beyond the income turning point. This implies that the environmental impact indicator is an inverted U-shaped function of income per capita as illustrates in figure 1. (Mishra, 2020)

Figure (1): Environmental Kuznets Curve hypothesis



Source: Mishra, M. K. (2020), "The Kuznets Curve for the Sustainable Environment and Economic Growth", Working Paper, Leibniz Information Centre for Economic, Hamburg.

3. The Econometric Framework of Environmental Kuznets Curve Hypothesis

Basically, the EKC focuses on the relationship between income and environmental factors. In general form, the EKC hypothesis is formulated as follows (Shuai *et al.*, 2017)

$$E = f(Y, Y^2, Z) \tag{1}$$

In this formulation, E denotes the environmental indicator, Y denotes income and Z denotes an explanatory variable which is supposed to affect environmental degradation. So, the standard EKC model takes the following, (Mishra, 2020)

$$Z_{it} = \beta_0 + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta . X_{it} + \varepsilon_{it} \qquad (2)$$

Where: Z_{it} emissions per capita in locality i, at time t, coefficients β_i, independent variable GDP per capita Y_{it}, other explaining factors X_{it} and error term ε_{it}
The turning point (TP) of GDP per capita, is given by deriving the quadratic functions of equality. So, the TP of GDP per capita is: (Yazgan *et al*., 2022)

$$Y_{it} = exp \frac{-\beta_{1t}}{2\beta_{2t}} \qquad (3)$$

The turning years is calculated by the following equation (Yazgan *et al*., 2022)

$$FV = PV * (1 + r)^n \qquad (4)$$

where FV is the future value of GDP per capita, PV is the present value of GDP per capita, r is the average growth rate, and n is the number of years.

4. Literature Review and Empirical Studies

Some researchers examined the ECK hypothesis at a reginal level. For instance, the results of (Zaekhan and Nachrowi, 2012) confirmed the existence of Environmental Kuznet's Curve (EKC) hypothesis in panel data of G-20 countries for the period of 2001-2010. The results of (Cheng *et al*., 2019) did not support the EKC hypothesis in 35 OECD countries from 1996 to 2015. The empirical results of (Anser *et al*., 2020) showed an Inverted-U shaped relationship between economic growth and carbon emissions and verified the existence of the environmental Kuznets curve for a panel of 16 middle- and lower-middle-income economies of Latin America and the Caribbean for the period 1990 to 2015. (Carlos Leitão *et al*., 2021) validated the arguments of the EKC hypothesis in BRICS countries (Brazil, Russia, India, China, and South Africa) from 1990 to 2015. The results of (Djellouli *et al*., 2022) focused on examining the existence of ECK in 20 African Countries. The results indicated that Environmental Kuznets Curve hypothesis did not hold in their sample.

Other researchers have focused on examining the existence of EKC in individual countries. For example, (Xu *et al*., 2012) supported the EKC hypothesis in China during the period 1980-2008. (Ahmed and Long, 2012) demonstrated the existence of EKC for the case of Pakistan with yearly data from 1971 to 2008. (Bouznit and Pablo-Romero, 2016) confirmed the EKC in Algeria during the period 1970-2010 but the threshold level of income was not reached yet. The results of (Sunde, 2018) showed that the

Environmental Kuznets Curve (EKC) was found in Namibia for the period of 1991: q1-2016: q4.

The above literature showed that various researches have focused on testing the EKC hypothesis for an individual country or at a regional level. A few researches have been conducted to identifying Turning Point. (Galeotti *et al*., 2006) emphasized that identifying turning point could be helpful when governments make reduction targets and adopts relevant strategies.

5. Testing Environmental Kuznets Curve Hypothesis in Africa

5.1 Hypothesis of the study

The literature review allows to compose a set of hypotheses to be tested in the empirical study.

Hypothesis 1 (H1). The Environmental Kuznets Curve hypothesis which said that in an initial phase of growth, economic activities cause carbon dioxide emissions increase. Consequently, in a development phase, economies gain realization of sustainability; thus, carbon dioxide emissions are expected to decrease. According to the environmental Kuznets curve assumptions, an inverted U-shape curve is expected between income per capita, squared income per capita, and carbon dioxide emissions (CE). Thus, the elasticities of income will be (GDP > 0) and ($GDP^2 < 0$)

Hypothesis2 (H2). Renewable energy intends to improve the environmental damage. A negative impact of renewable energy on carbon dioxide emissions (CE) is anticipated. Therefore, the elasticity of renewable energy is (RE < 0).

5.2 Materials and Methods

Based on the available data, the whole African countries comprised 48 countries (will be denoted as a whole Africa). The rest of them 6 countries South Sudan, Djibouti, Eritrea, Liberia, Somalia, and Sao Tome and Principe were excluded due to the lack of sufficient data for those countries in the period under study from 1990 to 2019.

Hence, the 48 countries were divided according to the income groups issued by the World Bank into four groups (low-income countries, lower middle-income countries, upper middle-income countries, and high-income countries), as illustrated in table No. (1).

Table No. 1: Thresholds for classification by income for African Countries

M	Income Threshold	African countries in each category	Number of countries
1	Low-income countries	Burkina Faso, Burundi, Central African Republic, Chad, Congo, Dem. Rep., Ethiopia, Gambia, Guinea, Guinea Bissau, Madagascar, Malawi, Mali, Mozambique, Niger, Rwanda, Sierra Leone, Togo, Uganda, Sudan, Zambia	20

2	Lower middle-income countries	Algeria, Angola, Benin, Cape Verde, Cameroon, Comoros, Congo, Rep., Côte d'Ivoire, Egypt, Ghana, Kenya, Lesotho, Mauritania, Morocco, Nigeria, Senegal, Swaziland, Tanzania, Tunisia, Zimbabwe	20
3	Upper middle-income countries	Botswana, Gabon, Libya, Mauritius, Namibia, South Africa, Equatorial Guinea	7
4	High income countries	Seychelles	1
5	Africa	All of the aforementioned countries in the four groups	48

Source: Prepared by the researcher according to the World Bank database

World Bank. 2022. Low income | Data (worldbank.org), Lower middle income | Data (worldbank.org), Upper middle income | Data (worldbank.org), High income | Data (worldbank.org)

The previous applied studies were relied upon to determine the study variables, which were as follows:

Dependent variable: The dependent variable in this study was CO_2 emission per capita in metric ton, and was symbolized CE.

Independent Variables: The study relied on several independent variables: GDP per capita at constant prices for 2015 in US dollars and expressed in the symbol GDP, as well as the square of GDP per capita as GDP^2, renewable energy consumption as a percentage of the total energy consumption expressed by the symbol RE, and urbanization expressed as a percentage of the urban population to the total population, expressed as URB. The data under study from 1990 to 2019 were obtained from the World Bank database, World Development Indicator. (World Bank, 2023)

5.3 Empirical Results and Discussion

In the following, the applicability of the hypothesis of the environmental Kuznets curve was tested five times for 48 countries and the four groups.

5.3.1 Stationary of Cross-sectional time-series

Two tests were used to study cross-sectional time-series stationary, which are the Levin, Lin and Chu (LLC) test (Levin *et al*., 2002) as well as the Im, Pesaran and Shin (IPS) test (Im *et al*., 2003). In these two tests, the null hypothesis is represented in the presence of a unit root, that is, the time series is not static. The alternative hypothesis is the absence of a unit root, that is, the time series is stationary. If the P-value is less than 0.05, the null hypothesis is rejected and thus the time series is static. (Harris *et al*., 2008)

Table No. 2: Panel unit root test using the LLC test

LLC test in Africa			
Variables	Statistic		Decision
	Level	First difference	
CE	1.45366	-13.3203***	Stationary at first difference
GDP	4.81002	-9.82536***	Stationary at first difference
RE	0.35336	-14.2826***	Stationary at first difference
URB	-3.30836 ***	-	Stationary at level
LLC test in African Low-income Countries			
Variables	Statistic		Decision
	Level	First difference	
CE	4.45839	-8.58706***	Stationary at first difference
GDP	2.69935	-7.92239***	Stationar3y at first difference
RE	3.15973	-7.75646***	Stationary at first difference
URB	6.14565	-0.43199 **	Stationary at first difference
LLC test in African lower middle-income countries			
Variables	Statistic		Decision
	Level	First difference	
CE	-0.39861	-8.29080***	Stationary at first difference
GDP	2.38714	-4.76876***	Stationary at first difference
RE	-0.13864	-10.6760***	Stationary at first difference
URB	-4.50508***	–	Stationary at level
LLC test in African upper middle-income countries			
Variables	Statistic		Decision
	Level	First difference	
CE	-1.24020	-5.63237***	Stationary at first difference
GDP	3.58877	-3.68847***	Stationary at first difference
RE	-2.33966	-5.56616***	Stationary at first difference
URB	-0.23733 ***	–	Stationary at level

Source: Prepared by the researcher based on EViews 12
***** (1%), and ** (5%) significance levels.**

The results obtained in table No. (2) referred to the results of the unit root test based on the LLC tests in Africa, low-income African countries, lower middle-income African countries, and upper-middle-income African countries. Conspicuously, it could be concluded that all the variables of the study were not stationary at the level and stabilized when the first difference was taken, except for the urbanization variable, which was stable at the level. Regarding the low-income African countries, all the variables were unstable at the level and stabilized at the first difference; therefore, all the variables, whether in the total 48 African countries or in the three groups, were integrated at degree I (0) or I (1).

Table No. 3: Panel unit root test using the IPS test

Variables	Statistic		Decision
IPS Test in Africa			
	Level	First difference	
CE	4.25069	-17.2999***	Stationary at first difference
GDP	7.86300	-12.5169***	Stationary at first difference
RE	3.59210	-16.8118***	Stationary at first difference
URB	-9.42633 **	-	Stationary at level
IPS Test in African Low-income Countries			
Variables	Statistic		Decision
	Level	First difference	
CE	4.14278	-9.72790***	Stationary at first difference
GDP	3.82253	-9.39485***	Stationary at first difference
RE	3.98168	-9.81637***	Stationary at first difference
URB	11.2994	-2.43325***	Stationary at first difference
IPS Test in African lower middle-income countries			
Variables	Statistic		Decision
	Level	First difference	
CE	2.09409	-12.7246***	Stationary at first difference
GDP	5.97468	-6.13053***	Stationary at first difference
RE	2.34557	-12.5601***	Stationary at first difference
URB	-3.69223***	-	Stationary at level
IPS test in African upper middle-income countries			
Variables	Statistic		Decision
	Level	First difference	
CE	0.20402	-6.30358***	Stationary at first difference
GDP	3.33971	-5.57164***	Stationary at first difference
RE	-0.86111	-5.56603***	Stationary at first difference
URB	-1.66903***	_	Stationary at level

Source: Prepared by the researcher based on EViews 12
***** (1%), and ** (5%) significance levels.**

The data presented in Table No. (3) showed the unit root test results using the IPS test, which exhibited the same results that were reached by relying on the LLC test; consequently, all the variables in Africa and the three groups were integrated at degree I (0) or I (1).

5.3.2 Cointegration test for cross-sectional time-series data

Prior to estimating the long run model, a cointegration relationship between the variables needs to be confirmed. Hence, for Africa and the three groups, three cointegration tests were conducted for cross-sectional time-series data, namely Pedroni Cointegration Test, Kao Residual Cointegration Test, and Johansen Fisher Panel Cointegration Test, in order to clarify the result that will be obtained by more than one test.

5.3.2.1 Pedroni Cointegration Test

Pedroni cointegration test (Pedroni,1999) indicates in the null hypothesis, there is no existence of cointegration (Neal, 2014). The test was applied on Africa and the three groups, as indicated by the results in Table (4), which showed that all test statistics for Africa and the three groups were less than 0.05; therefore, reject the null hypothesis that there is no existence of cointegration and accordingly accept the alternative hypothesis that there is cointegration and long-term equilibrium relationship between the study variables for Africa as well as and the three groups.

Table No. 4.: Results of Pedroni cointegration test

Pedroni cointegration test in Africa		
common AR coefs. (Within-dimension)		
	Statistic	Prob
Panel v- Statistic	0.478986	0.0316
Panel rho- Statistic	1.046927	0.0252
Panel PP- Statistic	-5.702923	0.0000
Panel ADF- Statistic	-6.717156	0.0000
individual AR coefs. (Between-dimension)		
	Statistic	Prob
Group rho-Statistic	3.249526	0.0094
Group PP-Statistic	-6.304893	0.0000
Group ADF-Statistic	-5.354619	0.0000
Pedroni cointegration test in African Low-income Countries		
common AR coefs. (Within-dimension)		
	Statistic	Prob
Panel v- Statistic	-1.875037	0.0396
Panel rho- Statistic	1.082228	0.0304
Panel PP- Statistic	-2.379396	0.0087
Panel ADF- Statistic	-2.895129	0.0019
individual AR coefs. (Between-dimension)		
	Statistic	Prob
Group rho-Statistic	2.292950	0.0481
Group PP-Statistic	-1.650775	0.0494
Group ADF-Statistic	-1.380914	0.0537
Pedroni cointegration test in African lower middle-income countries		
common AR coefs. (Within-dimension)		
	Statistic	Prob
Panel v- Statistic	3.105087	0.0010
Panel rho- Statistic	1.644991	0.0500
Panel PP- Statistic	-2.129441	0.0166
Panel ADF- Statistic	-4.218724	0.0000
individual AR coefs. (Between-dimension)		
	Statistic	Prob
Group rho-Statistic	1.875904	0.0497
Group PP-Statistic	-4.781564	0.0000
Group ADF-Statistic	-6.176954	0.0000

Pedroni cointegration test in African upper middle-income countries		
common AR coefs. (Within-dimension)		
	Statistic	Prob
Panel v- Statistic	0.128819	0.0488
Panel rho- Statistic	0.363601	0.0419
Panel PP- Statistic	-2.259353	0.0119
Panel ADF- Statistic	-2.589637	0.0048
individual AR coefs. (Between-dimension)		
	Statistic	Prob
Group rho-Statistic	1.173958	0.0098
Group PP-Statistic	-5.666807	0.0000
Group ADF-Statistic	-1.052205	0.0464

Source: Prepared by the researcher based on EViews 12

5.3.2.2 Kao Residual Cointegration Test

Kao residual cointegration test (kao, 1999), (Kao and Chiang, 2001) is one of the important tests that are used to detect the presence or absence of cointegration in cross-sectional time-series data, where the Augmented Dickey-Fuller (ADF) is used to test the null hypothesis that there is no cointegration in the panel data as opposed to the alternative hypothesis that there is a cointegration. (Barbieri, 2008).

Table No. (5) indicates the results of the application of the Kao residual cointegration test in Africa and the three groups, and since the test statistic was significant at less than 5%, it could be said that the alternative hypothesis is accepted and hence, there is cointegration in Africa and the three groups.

Table No. 5.: Results of Kao residual cointegration Test

Kao residual cointegration test in Africa		
	t-Statistic	Prob.
ADF	-8.611515	0.0000
Kao residual cointegration test in African Low-income Countries		
	t-Statistic	Prob.
ADF	-3.076387	0.0010
Kao residual cointegration test in African lower middle-income countries		
	t-Statistic	Prob.
ADF	-1.878742	0.0301
Kao residual cointegration test in African upper middle-income countries		
	t-Statistic	Prob.
ADF	-3.296412	0.0005

Source: Prepared by the researcher based on EViews 12

5.3.2.3 Johansen Fisher Panel Cointegration Test

A third test was applied to verify the results obtained from the two previous tests, which is the Johansen Fisher panel cointegration test (Bidirici and Bohur, 2015), (Toyoshima and Hamori, 2011). Results in Table No. (6) exhibited the same previous trend, in which the alternative hypothesis is accepted, thus, that there is a cointegration for Africa and the three groups, therefore there is a long-term equilibrium relationship between the variables under study.

Table No. 6.: Results of Johansen Fisher panel cointegration test

Johansen Fisher panel cointegration test in Africa				
Hypothesized No. of CE(s)	Fisher Stat. (from trace test)	Prob.	Fisher Stat. (from max-eigen test)	Prob.
None	1012.	0.0000	594.6	0.0000
At most 1	524.3	0.0000	313.6	0.0000
At most 2	283.7	0.0000	193.2	0.0000
At most 3	174.9	0.0000	137.8	0.0033
At most 4	180.0	0.0000	180.0	0.0000
Johansen Fisher panel cointegration test in African Low-income Countries				
Hypothesized No. of CE(s)	Fisher Stat. (from trace test)	Prob.	Fisher Stat. (from max-eigen test)	Prob.
None	447.9	0.0000	268.6	0.0000
At most 1	219.2	0.0000	129.9	0.0000
At most 2	119.6	0.0000	78.59	0.0003
At most 3	76.52	0.0004	60.11	0.0214
At most 4	78.03	0.0003	78.03	0.0003
Johansen Fisher panel cointegration test in African lower middle-income countries				
Hypothesized No. of CE(s)	Fisher Stat. (from trace test)	Prob.	Fisher Stat. (from max-eigen test)	Prob.
None	442.8	0.0000	252.9	0.0000
At most 1	243.4	0.0000	144.9	0.0000
At most 2	130.1	0.0000	94.24	0.0000
At most 3	72.09	0.0014	58.84	0.0277
At most 4	68.74	0.0031	68.74	0.0031
Johansen Fisher panel cointegration test in African upper middle-income countries				
None	102.8	0.0000	63.88	0.0000
At most 1	50.92	0.0000	35.25	0.0013
At most 2	25.43	0.0305	15.39	0.0521
At most 3	20.58	0.0130	15.23	0.0324
At most 4	26.91	0.0198	26.91	0.0198

Source: Prepared by the researcher based on EViews 12

5.3.3 Estimation of cross-sectional time series models

It is important to estimate the study model using the three cross-sectional time-series data models, namely, the Pooled Regression model, the fixed effects model, and the random effects model. (Zulfikar, 2018)

In the Pooled Regression Model (PRM), the individual effect is the same for all cross-sectional data. (Raffalovich and Chung, 2014)

In the Fixed Effects Model (FEM), the objective of the individual effect in Fixed Effects Model is to know the behavior of each cross-sectional data set separately. (Schmidheiny, 2011)

In the Random Effects Model (REM), it is usually assumed that the error variance is constant, that is, homogeneous for all cross-sectional observations, and there is no autocorrelation during time between each group of cross-sectional observations in a specific time period. (Baltagi, 2005).

The estimation equations have been formulated in natural logarithm form to ensure homoscedasticity of the coefficients representing the elasticities of the relationships under investigation as shown in equations No. 5,6,7,8

The estimation model for the 48 African countries as follows:

$$lnCE_{it} = \beta_{0i} + \beta_1\, lnGDP_{it} + \beta_2 lnGDP_{it}^2 + \beta_3 lnRE_{it} + \beta_4 lnURB_{it} \quad (5)$$
$$i = 1 \dots .48 \quad t = 1990 \dots \dots 2019$$

For the African low-income countries, the estimation model came in the following form:

$$lnCE_{it} = \beta_{0i} + \beta_1\, lnGDP_{it} + \beta_2 lnGDP_{it}^2 + \beta_3 lnRE_{it} + \beta_4 lnURB_{it} \quad (6)$$
$$i = 1 \dots .20 \quad t = 1990 \dots \dots 2019$$

Regarding the lower middle-income African countries, the estimation model was as follows:

$$lnCE_{it} = \beta_{0i} + \beta_1\, lnGDP_{it} + \beta_2 lnGDP_{it}^2 + \beta_3 lnRE_{it} + \beta_4 lnURB_{it} \quad (7)$$
$$i = 1 \dots .20 \quad t = 1990 \dots \dots 2019$$

While the estimation model for the upper middle-income African countries was as follows:

$$lnCE_{it} = \beta_{0i} + \beta_1\, lnGDP_{it} + \beta_2 lnGDP_{it}^2 + \beta_3 lnRE_{it} + \beta_4 lnURB_{it} \quad (8)$$
$$i = 1 \dots .7 \quad t = 1990 \dots \dots 2019$$

Table No. 7: Estimation of the study model using the three models

Estimation for Africa			
Variables	Random Effects Model (REM)	Fixed Effects Model (FEM)	Pooled Regression Model (PRM)
C	1.270569***	1.363084***	-
GDP	0.000290***	0.000268***	0.000663***
GDP^2	-1.16E-05***	-1.29E-05***	-1.61E-05***
RE	-0.011618**	-0.011705***	-0.006411***
URB	-0.003981**	-0.005274**	0.005756***
Adjusted R^2	0.711866	0.971465	0.800681
F	889.7996***	961.6028***	-
Estimation for African Low-income Countries			
Variables	Random Effects Model (REM)	Fixed Effects Model (FEM)	Pooled Regression Model (PRM)

c	0.506442***	0.515442***	-
GDP	9.21E-05***	8.77E-05***	0.000169***
GDP^2	1.26E-08***	1.32E-08***	-6.80E-09**
RE	-0.005904***	-0.006025***	-0.000609***
URB	0.002054***	0.002176***	0.002911***
Adjusted R^2	0.693232	0.913284	0.647229
F	339.4045***	275.2861***	-
Estimation for African lower middle-income countries			
Variables	Random Effects Model (REM)	Fixed Effects Model (FEM)	Pooled Regression Model (PRM)
c	0.583225***	0.562868***	-
GDP	0.000335***	0.000335***	0.000429***
GDP^2	7.80E-09***	7.75E-09**	1.90E-08***
RE	-0.005473***	-0.004743***	-0.008085***
URB	-0.001831***	-0.002283	0.009673***
Adjusted R^2	0.515933	0.957977	0.777656
F	160.6079***	594.7057***	-
Estimation for African upper middle-income countries			
Variables	Random Effects Model (REM)	Fixed Effects Model (FEM)	Pooled Regression Model (PRM)
c	3.420451***	3.784611***	-
GDP	0.000175***	0.000155***	1.40E-08***
GDP^2	-1.87E-05***	-2.08E-05***	-2.67E-05***
RE	-0.019805***	-0.019162**	-0.060435***
URB	-0.001168	-0.006505**	0.104686***
Adjusted R^2	0.722104	0.930481	0.679717
F	136.7697***	280.7370***	-

Source: Prepared by the researcher based on EViews 12

***** (1%), and ** (5%) significance levels.**

The results presented in Table (7) exhibited the estimation of the parameters of the study model based on the three models, which are pooled regression model, fixed effects model, and random effects model for the aforementioned groups.

5.3.4 Choosing the appropriate model

5.3.4.1 Chow Test

The Chow test is used to choose between the pooled regression model and the fixed effects model to find out which of them is best for estimating panel data (Binkley and Young, 2020). According to this test, the null hypothesis indicated that the pooled regression model is the best, while the alternative hypothesis indicated that the fixed effects model was the most convenient. (Lee, 2008) When the level of significance is less than 0.05, the alternative hypothesis is accepted, meaning that the fixed effects model is appropriate (Ghilagaber, 2004).

Table No. 8.: Results of Chow test

Chow test in Africa		
	Statistic	Prob.
Cross-section Chi-square	2846.009857	0.0000
Chow test in African Low-income Countries		
	Statistic	Prob.
Cross-section Chi-square	726.986895	0.2173
Chow test in African lower middle-income countries		
	Statistic	Prob.
Cross-section Chi-square	1005.112864	0.0000
Chow test in African upper middle-income countries		
	Statistic	Prob.
Cross-section Chi-square	327.838230	0.0000

Source: Prepared by the researcher based on EViews 12

The results of the Chow test presented in Table No. (8) showed that for Africa, the test value was 2846,009 at a level of significance less than 5%, and the lower middle-income African countries, the test value was 1005,112 at a level of significance less than 5%, and upper middle-income African countries the test value was 327,838 at a significance level of less than 5%, so, the fixed effects model is the most suitable for Africa, lower middle-income African countries, and upper middle-income African countries, where the null hypothesis of homogeneity of country segments was rejected, which indicated the magnitude of including cross-sectional and temporal effects in the model, unlike what was achieved for low-income African countries, where the test value was 726,986 at a level of significance greater than 5%, and therefore the null hypothesis was accepted, and the appropriate model was the pooled regression model.

5.3.4.2 Hausman Test

The Hausman test (Hausman and Taylor, 1981) was used to choose between the fixed effects model and the random effects model, where the null hypothesis indicated that the random effects model was appropriate, while the alternative hypothesis indicated that the fixed effects model was appropriate. (Bell and Kelvyn, 2015). That is, constant individual differences and differences among countries in relation to the levels of per capita GDP affect the levels of environmental degradation in them.

Table No. 9.: Results of Hausman test

Hausman test in Africa		
	Chi-Sq. Statistic	Prob.
Cross-section random	44.582522	0.0000
Hausman test in African low-income countries		
	Chi-Sq. Statistic	Prob.
Cross-section random	6.317434	0.1767
Hausman test in African lower middle-income countries		
	Chi-Sq. Statistic	Prob.
Cross-section random	16.982956	0.0019

Hausman test in African upper middle-income countries		
	Chi-Sq. Statistic	Prob.
Cross-section random	21.782479	0.0002

Source: Prepared by the researcher based on EViews 12

The results contained in Table No. (9) revealed that the statistic of the test in Africa was 44,582, which is significance at 5%, and in lower middle-income African countries was 16,982, which indicated significance at 5%, and in upper middle-income African countries was 21,782, which was significance at 5%. Thus, the fixed effects model is considered appropriate for Africa, the lower middle income African countries, and the upper middle income African countries, unlike the case for the low-income African countries in which the random effects model was appropriate.

So, for Africa, lower middle-income African countries, and upper middle-income African countries, it has been confirmed that the appropriate model for them is fixed effects model.

5.3.4.3 Lagrange Multiplier Test

As for low-income African countries, another test, Lagrange Multiplier Test was employed to determine the best method in panel data regression, whether to use pooled regression model or random effects model. The Lagrange Multiplier test possessed a function to determine the best estimate, whether using a random effect or not. (Zulfikar, 2018)

The results presented in Table No. (10) pointed out that the null hypothesis, which revealed that the appropriate model was pooled regression model, was rejected, and the alternative hypothesis was accepted, which indicates that the appropriate model was the random effects model.

Table No. 10.: Results of Lagrange Multiplier test

	Statistic	Prob.
Breusch- Pagan LM test	963.4206	0.0000

Source: Prepared by the researcher based on EViews 12

5.3.5 Estimation of long-run parameters of cross-sectional time series

After it has been reached that there is a long-term equilibrium relationship between the model variables in Africa, African low-income countries, African lower middle-income countries, and African upper middle-income countries, the long-term parameters were estimated by the Dynamic Ordinary Least Squares D-OLS Panel models (Melo-Velandia *et al*., 2015), where this method has the advantage of eliminating the deviations in the static regression by including Dynamic elements in the model. (Mark and Sul, 2003)

Table No. 11.: Results of Panel D- OLS

Panel D- OLS in Africa				
Variable	Coefficient	Std.Error	t-Statistic	Prob
GDP	0.000725	6.16E-05	11.76300	0.0000
GDP^2	-3.91E-05	3.29E-06	-6.548293	0.0000
RE	-0.008574	0.002916	-2.939983	0.0034
URB	-0.025228	0.005486	-4.599021	0.0000
R-squared	0.995691	Mean dependent var	1.179457	
Adjusted R-squared	0.991646	S.D. dependent var	1.993615	
S.E. of regression	0.182220	Sum squared resid	22.18043	
Long-run variance	0.020169			
Panel D- OLS in African low-income countries				
Variable	Coefficient	Std.Error	t-Statistic	Prob
GDP	-8.06E-05	4.55E-05	-1.771779	0.0775
GDP^2	1.16E-07	1.65E-08	7.018301	0.0000
RE	-0.002463	0.000613	-4.021388	0.0001
URB	0.007242	0.001005	7.205761	0.0000
R-squared	0.985159	Mean dependent var	0.129072	
Adjusted R-squared	0.971016	S.D. dependent var	0.096062	
S.E. of regression	0.016354	Sum squared resid	0.073819	
Long-run variance	0.000206			
Panel D- OLS in African lower middle-income countries				
Variable	Coefficient	Std.Error	t-Statistic	Prob
GDP	0.000296	0.000133	2.221090	0.0272
GDP^2	7.66E-09	2.44E-08	0.314062	0.7537
RE	-0.004253	0.001982	-2.146328	0.0327
URB	-0.009911	0.004578	-2.164799	0.0313
R-squared	0.995289	Mean dependent var	0.864779	
Adjusted R-squared	0.990801	S.D. dependent var	0.787467	
S.E. of regression	0.075529	Sum squared resid	1.574464	
Long-run variance	0.004389			
Panel D- OLS in African upper middle-income countries				
Variable	Coefficient	Std.Error	t-Statistic	Prob
GDP	0.001111	0.000436	2.548898	0.0124
GDP^2	-6.08E-05	1.99E-04	-2.000126	0.0484
RE	-0.004614	0.022552	-0.204572	0.0383
URB	-0.069166	0.026924	-2.568962	0.0118
R-squared	0.988894	Mean dependent var	4.628261	
Adjusted R-squared	0.977787	S.D. dependent var	2.929500	
S.E. of regression	0.436612	Sum squared resid	17.91925	
Long-run variance	0.112380			

Source: Prepared by the researcher based on EViews 12

The variables that analyze the environmental Kuznets curve (income per capita and squared income per capita) their coefficients confirmed a positive and negative impacts on carbon dioxide emissions, and these were statistically significance at 1% and 5% levels in Africa, and African upper middle-income countries as illustrated in table No. (11). So, they confirmed the EKC hypothesis, unlike in the case of low-income African countries, and lower middle-income African countries, therefore the hypothesis of the EKC did not apply to them.

Table No. 12: Coef. Using Panel (DOLS), and FEM

Estimation in Africa		
Variables	Panel D- OLS	FEM
GDP	0.000725***	0.000268***
GDP^2	-3.91E-05***	-1.29E-05***
RE	-0.008574***	-0.011705***
URB	-0.025228***	-0.005274**
Estimation in African upper middle-income countries		
Variables	Panel D- OLS	FEM
GDP	0.001111***	0.000155***
GDP^2	-6.08E-05***	-2.08E-05***
RE	-0.004614***	-0.019162**
URB	-0.069166***	-0.006505**

Source: Prepared by the researcher based on EViews 12
***** (1%), and ** (5%) significance levels.**

Table (12) displayed the Coefficient using Panel D- OLS and Fixed Effects Model (FEM) in Africa and African upper middle-income countries which indicated that the variables that elaborate the environmental Kuznets curve (income per capita and squared income per capita) their coefficients in both Panel D- OLS and FEM confirmed a positive and negative effects on carbon dioxide emissions, and they were statistically significance at a 1% level, so, they validated hypothesis H1 of the research. Also, renewable energy (RE) variable was negatively associated with carbon dioxide emissions and demonstrated a negative correlation between renewable energy and CO_2 emissions and it validated hypothesis H2

5.3.6 Stationary of time series

As for the fourth group, which belong the high-income countries, since there was only one country in Africa, which is Seychelles, and therefore the unit root was tested according to the tests used to analyze time series, the most famous of which is the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1981) and Phillips – Perron (PP) test (Phillips and Perron, 1988).

The results in Table (13) indicated that for the test of the Augmented Dickey-Fuller, two variables came static at the level and two variables came static at the first difference. Also, the results of Philips Perron test, were similar to those of Augmented Dickey-Fuller Test.

Table No. 13.: Unit Root Test in Seychelles

ADF test results in Seychelles			
Variables	Statistic		Decision
	Level	First difference	
CE	-0.762142	-6.014096***	Stationary at first difference
GDP	0.659738	-3.956446***	Stationary at first difference
RE	-3.625939**	-	Stationary at first difference
URB	-2.298190**	-	Stationary at level
PP test results in Seychelles			
Variables	Statistic		Decision
	Level	First difference	
CE	-0.664692	-6.734339***	Stationary at first difference
GDP	2.570431	-4.049719***	Stationary at first difference
RE	-4.431958***	-	Stationary at first difference
URB	-2.540274**	-	Stationary at level

Source: Prepared by the researcher based on EViews 12
***** (1%), and ** (5%) significance levels.**

5.3.7 Cointegration test for time-series data

The fourth group includes only Seychelles, and thus the cointegration test was applied for time-series data; the most famous of which is the Johansen Cointegration Test (Johansen, 1988). There are two tests to determine the number of co-integration vectors trace test and maximal eigen value.

According to the results contained in Table (14), the calculated value of the two tests statistic was greater than the tabulated value; then the null hypothesis was rejected and the alternative hypothesis was accepted, as there are four vectors of cointegration, and this indicates the existence of a long-term equilibrium relationship among the variables under study.

Table No. 14.: Results of Johansen cointegration test in Seychelles

Trace test			
Hypothesized No. of CE(s)	Trace Statistic	Critical Value 0.05	Prob.
None	97.02113	69.81889	0.0001
At most 1	57.68724	47.85613	0.0046
At most 2	34.56455	29.79707	0.0131
At most 3	15.03777	15.49471	0.0585
At most 4	4.164757	3.841465	0.0413
Max-Eigen test			
Hypothesized No. of CE(s)	Max-Eigen Statistic	0.05 Critical Value	Prob.
None	39.33388	33.87687	0.0101
At most 1	23.12269	27.58434	0.0083
At most 2	19.52679	21.13162	0.0126
At most 3	10.87301	14.26460	0.0607
At most 4	4.164757	3.841465	0.0412

Source: Prepared by the researcher based on EViews 12

5.3.8 Estimation of long-run parameters of time series

The Dynamic Ordinary Least Square Method is a parametric method which is used to estimate the long-run equilibrium relationship when there are integrated variables of different degrees, but they are still co-integrated. (Pablo, 2010)

The estimation model for African high-income countries (Seychelles) during the period (1990-2019) has been formulated as follows:

$$lnCE_{it} = \beta_{0i} + \beta_1\, lnGDP_{it} + \beta_2 lnGDP_{it}^2 + \beta_3 lnRE_{it} + \beta_4 lnURB_{it} \quad (9)$$

Table No. 15.: Results of D- OLS in Seychelles

Variable	Coefficient	Std.Error	t-Statistic	Prob
GDP	0.000177	0.000958	0.184437	0.0514
GDP^2	-9.06E-06	4.36E-05	-0.063362	0.0507
RE	-0.569798	0.184448	-3.089206	0.0115
URB	0.553409	0.463833	1.193121	0.2604
R-squared	0.987325	Mean dependent var	4.339061	
Adjusted R-squared	0.967046	S.D. dependent var	1.029269	
S.E. of regression	0.186846	Sum squared resid	0.349114	
Long-run variance	0.021949			

Source: Prepared by the researcher based on EViews 12

The results in table No. (15) pointed out that environmental Kuznets curve was applicable in Seychelles as the coefficients of income per capita and squared income per capita confirmed a positive and negative effects on carbon dioxide emissions, and these were statistically significance at 5% level, so, they validated hypothesis H1 in Seychelles. Also, renewable energy (RE) variable was negatively associated with carbon dioxide emissions and demonstrated a negative correlation between renewable energy and CO_2 emissions and it validated hypothesis H2 in Seychelles.

Therefore, the study concludes that the hypotheses of environmental Kuznets curve are applicable for Africa, upper middle income African countries and High-income African countries.

5.3.9 Estimation of turning point and turning years

In order to provide African countries with important references about turning points and turning years to reduce carbon emission, results in Table No. (16) showed that for Africa the turning point of GDP per capita will be reached at 10601.27 US. Dollars, where it needs 14 years to reach that level at growth rate of 0.098. For upper middle income African countries, it needs 8 years to reach GDP per capita level at 9288.32 US. Dollars at 0.031 growth rate. Finally for High-income African countries (Seychelles) it needs one year to reach GDP per capita level at 17469.5 US. Dollars at 0.021growth rate.

The results also indicated that there was variation among groups in turning points and turning years. So, the higher the average per capita GDP, the fewer years required to reach the turning point in the per capita level of GDP.

Table No. 16.: Turning point and turning years for environmental Kuznets curve

	GDP per capita (2019)	Growth rate	Turning point	Turning years
Africa	2742.41	0.098201	10601.27	14
Upper middle income African countries	7372.5	0.031472	9288.32	8
High-income African countries (Seychelles)	16989.96	0.021761	17469.5	1

Source: Prepared and calculated by the researcher based on the results obtained from EViews 12

5.3.10 Causality Tests

According to cointegration methods, if there is a long-run relationship between variables, a causality relationship must exist in at least one direction (Bidiricia and Bohur, 2015). One of the most important tests that can be applied in this framework is the Pairwise Granger Causality Tests. Granger introduced the concept of causality in econometrics in 1969 (Granger,1969 & 1988).

The results of Granger Causality test relationship variables analyzed is shown in Table No. (17). As it has been seen in the results, for Africa and African low-income countries, there were unidirectional causality relationship from GDP to carbon dioxide, renewable energy consumption to GDP, and from renewable energy consumption to carbon dioxide.

For African lower middle-income countries, African upper middle-income countries and African high-income countries there were unidirectional causality relationship from GDP to carbon dioxide, and from renewable energy consumption to carbon dioxide; but there was bidirectional causality between renewable energy consumption to GDP.

Table No. 17.: Results of Pairwise Granger Causality Tests

Pairwise Granger Causality Test in Africa			
Null Hypothesis	Obs	F-Statistic	Prob.
GDP does not Granger Cause CE	1344	2.07775	0.0256
CE does not Granger Cause GDP		14.7387	5.E-07
RE does not Granger Cause GDP	1344	13.3808	0.0219
GDP does not Granger Cause RE		3.83358	2.E-06
RE does not Granger Cause CE	1344	11.1685	0.0430
CE does not Granger Cause RE		3.15459	2.E-05
Pairwise Granger Causality Test in African Low-income Countries			
Null Hypothesis	Obs	F-Statistic	Prob.
GDP does not Granger Cause CE	560	10.4746	0.0354
CE does not Granger Cause GDP		3.36089	3.E-05
RE does not Granger Cause GDP	560	0.31279	0.0315
GDP does not Granger Cause RE		0.84128	0.4317
RE does not Granger Cause CE	560	0.31279	0.0315
CE does not Granger Cause RE		0.84128	0.4317

Pairwise Granger Causality Test in African lower middle-income countries			
Null Hypothesis	Obs	F-Statistic	Prob.
GDP does not Granger Cause CE	560	3.57979	0.0285
CE does not Granger Cause GDP		0.46574	0.6279
RE does not Granger Cause GDP	560	6.35998	0.0019
GDP does not Granger Cause RE		3.22866	0.0404
RE does not Granger Cause CE	560	9.14317	0.0001
CE does not Granger Cause RE		2.19508	0.1123
Pairwise Granger Causality Test in African upper middle-income countries			
Null Hypothesis	Obs	F-Statistic	Prob.
GDP does not Granger Cause CE	196	0.85598	0.0265
CE does not Granger Cause GDP		2.59375	0.4774
RE does not Granger Cause GDP	196	5.86931	0.0034
GDP does not Granger Cause RE		2.95737	0.0543
RE does not Granger Cause CE	196	5.59812	0.0043
CE does not Granger Cause RE		2.69387	0.1702
Pairwise Granger Causality Test in African high-income countries			
Null Hypothesis	Obs	F-Statistic	Prob.
GDP does not Granger Cause CE	28	1.12717	0.0412
CE does not Granger Cause GDP		1.44595	0.2561
RE does not Granger Cause GDP	28	7.50835	0.0031
GDP does not Granger Cause RE		3.31808	0.0343
RE does not Granger Cause CE	28	1.71796	0.0017
CE does not Granger Cause RE		0.23454	0.7928

Source: Prepared by the researcher based on EViews 12

6. Conclusion

The environmental Kuznets curve (EKC) hypothesis explains the relationship between economic activity and environmental degradation. Therefore, the countries need to know their situation of the EKC scheme to help in policies to make green economic growth of the countries effective in reducing CO_2 emissions and be able to achieve environmental sustainability.

This paper examines the dynamic effect of economic growth and renewable energy on environmental degradation to test the EKC hypothesis over the period 1990 to 2019 in the African continent, so, the paper treated with the continent as a whole, then separated it into four groups according to the world bank classification to explore the differences among those groups: The whole Africa (48 countries), African low-income countries (20 countries), African lower middle-income countries (20 countries), African upper middle-income countries (7 countries), and African high-income countries (1 country).

Therefore, the paper used different econometric tools to analyze panel data four times and time series data analysis one time.

The results of the unit root test for panel data based on LLC and IPS tests demonstrated that all the variables, whether in Africa or in the three groups, were integrated of degree I (0) or I (1). The results of the unit root test for time series analysis by using ADF and PP tests revealed that the variables were integrated of degree I (0) or I (1).

In addition, the paper applied Pedroni Cointegration Test ,Kao Residual Cointegration Test, and Johansen Fisher Panel Cointegration Test to check the cointegration in the long run. The results of the cointegration tests, exhibited that cointegration and long-term equilibrium relationship among the study variables for the whole Africa and the associated three groups. The results of the Johansen Cointegration Test assured the existence of a long-term equilibrium relationship for time series analysis.

The paper estimated three cross-sectional time-series data models, namely, the Pooled Regression model, the fixed effects model, and the random effects model for the whole Africa and the three groups. After applying Chow test, Hausman test and Lagrange Multiplier test, for the whole Africa and the lower middle income African countries, and the upper middle income African countries, the fixed effects model is the most convenient. Unlike the case for the low-income African countries in which the random effects model is considered appropriate.

The long-term parameters were estimated by the Dynamic Ordinary Least Squares D-OLS Panel models for the whole Africa and three groups. Applying econometric methodology panel- DOLS and fixed effects model revealed that the coefficients presented the same tendency between them. The econometric results obtained demonstrated that the environmental Kuznets curve is valid for the whole Africa, and African upper middle-income countries; their coefficients verified a positive and negative effect on carbon dioxide emissions, and these were statistically significance at 1% level, so, they validated hypothesis H1 of the research. Also, renewable energy (RE) variable was negatively associated with carbon dioxide emissions and demonstrated a negative correlation between renewable energy and CO_2 emissions and it validated hypothesis H2

The results of estimating Dynamic Ordinary Least Square Method for time series revealed that the environmental Kuznets curve is applicable in Seychelles. Also, hypothesis H2 considering renewable energy is applicable too.

Then, this paper estimated the turning points and turning years for groups where the ECK are valid. For the whole Africa the turning point of GDP per capita will be reached at 10601.27 US. Dollars at it needs 14 years to reach that level. For upper middle income African countries, it needs 8 years to reach GDP per capita level at 9288.32 US. Dollars. Finally, for High-income African countries (Seychelles) it needs one year to reach GDP per capita level at 17469.5 US. Dollars.

The results of Granger Causality tests for Africa and African low-income countries, exhibited a unidirectional causality relationship from GDP to carbon dioxide, renewable energy consumption to GDP, and from renewable energy consumption to carbon dioxide.

For African lower middle-income countries, African upper middle-income countries and African high-income countries, there were unidirectional causality relationship from GDP to carbon dioxide, and from renewable energy consumption to carbon dioxide. But there was bidirectional causality between renewable energy consumption to GDP.

Based on the results, several policy recommendations are proposed. Firstly, in order to reduce CO_2 emissions, the government of the African upper middle-income and high-income countries should realize the importance of energy saving, and encourage the use of renewable energy, which is the most effective way to reduce CO_2 emissions and has the least impacts on GDP. As for the African low income and lower middle-income countries, the governments should adjust their industry structures, aiming at building a low carbon economy structure.

Secondly, African countries should adopt different environmental and energy regulations through green economic growth that would restrict the use of unclean energy, fossil fuels and coal and offer incentives for using renewable energies. Therefore, switching non-renewable energy resources with renewable energy resources leads to energy efficiency and thereby improved environmental sustainability and achieve Sustainable Development Goals (SDG), especially SDG7 (affordable and clean energy) and SDG 13 (climate action).

Finally, for all African countries, if they want to decrease carbon dioxide emissions and reduce the negative impacts on the environment, they required to adopt environmental conservation policies, technological advancement and modern industrial policies which focus more on achieving green economic growth.

References

Adamowicz, M. (2022), "Green Growth and Green Economy as a Means of Support for Attaining the Sustainable Development Goals", *Sustainability*, Vol. 14, pp. 1-32.

Ahmed, K. and Long, W. (2012), "Environmental Kuznets Curve and Pakistan: An Empirical Analysis", *Procedia Economics and* Finance, Vol.1, pp. 4–13.

Anser, M. K., Hanif, I., Alharthi, M., and Chaudhry, I. S. (2020), "Impact of Fossil Fuels, Renewable Energy Consumption and Industrial Growth on Carbon Emissions in Latin American and Caribbean Economies", *Atmósfera*, Vol. 33 No. 3, pp. 201-213.

Baltagi, B. H. (2005), Econometric Analysis of Panel Data, Third Edition, John Wiley & Sons, New York.

Barbieri, L. (2008), "Panel Cointegration Tests: A Survey", *Rivista Internazionale di Scienze Sociali*, Vol.1, pp. 3-36.

Bell, A. and Jones, K. (2015), "Explaining Fixed Effects: Random Effects Modeling of Time-Series Cross-Sectional and Panel Data", *Political Science Research and Methods*, Vol. 3 No. 1, pp.133-153.

Bidirici, M. and Bohur, E. (2015), "Design and Economic Growth: Panel Cointegration and Causality Analysis", *Procedia - Social and Behavioral Sciences*, Vol. 210, pp.193–202.

Binkley, J. K. and Young, J. (2020), "The Chow Test with Time Series-Cross Section Data", *Faculty & Staff Research and Creative Activity*, Vol. 184, pp. 1-26.

Bouznit, M. and Pablo-Romero, M. P. (2016), "CO_2 Emission and Economic Growth in Algeria", *Energy Policy*, Vol. 96, pp. 93-104.

Carlos Leitão, N. Balsalobre-Lorente, D. and Cantos-Cantos, J. (2021), "The Impact of Renewable Energy and Economic Complexity on Carbon Emissions in BRICS Countries under the EKC Scheme", *Energies*, Vol. 14, pp.1-15.

Cheng, C. Ren, X. and Wang, Z. (2019), "The Impact of Renewable Energy and Innovation on Carbon Emissions: An Empirical Analysis for OECD Countries", *Energy Procedia*, Vol. 158, pp. 3506-3512.

Djellouli, N. Abdelli, L. Elheddad, M. Ahmed, R. and Mahmood, H. (2022), "The Effects of Non-Renewable Energy, Renewable Energy, Economic Growth, and Foreign Direct Investment on the Sustainability of African Countries", *Renewable Energy*, Vol. 183, pp. 676-686.

Dickey, D. A. and Fuller, W. A. (1981), "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root", *Econometrica*, Vol. 49 No. 4, pp. 1057-1072.

Galeotti, M. Lanza, A. and Francesco, P. (2006), "Reassessing the Environmental Kuznets Curve for CO2 Emissions: A Robustness Exercise", *Ecological Economics*, Vol. 57 No. 1, pp.152-163.

Ghilagaber, G. (2004), "Another Look at Chow's Test for the Equality of Two Heteroscedastic Regression Models", *Quality & Quantity*, Vol. 38, pp.81–93.

Granger, C. W. J. (1969), "Investigating Causal Relations by Econometric Models and Cross Spectral Methods", *Econometrica*, Vol. 37 No. 3, pp. 424-438.

Granger, C. W. J. (1988), "Some Recent Developments in a Concept of Causality", *Journal of Econometrics*, Vol.39 No. 1-2, pp.199-211.

Grossman, G. M. and Krueger, A. B. (1991), "Environmental Impacts of a North American Free Trade Agreement", Working Paper No. 3914, National Bureau of Economic Research, Cambridge, November.

Harris, D. Harvey, D. I. Leybourne, S. J. and Sakkas, N. D. (2008), "Local Asymptotic Power of the Im-Pesaran-Shin Panel Unit Root Test and the Impact of Initial Observations", Granger Centre for time series econometrics No. 08/02, School of Economics, University of Nottingham, Nottingham, March

Hausman, J. A. and Taylor, W. E. (1981), "Panel Data and Unobservable Individual Effects", *Econometrica*, Vol. 49 No. 6, pp. 1377-1398.

Im, K. S. Pesaran, M. H. and Shin, Y. (2003), "Testing for Unit Roots in Heterogeneous Panels", *Journal of Econometrics*, Vol. 115 No. 1, pp. 53-74.

Kao, c. (1999), "Spurious Regression and Residual-based Tests for Cointegration in Panel Data", Journal of Econometrics, Vol. 90 No. 1, pp. 1-44.

Jebli, M. B. Madaleno, M. Schneider, N. and Shahzad, U. (2022), "What does the EKC Theory leave behind? A state-of-the-art Review and Assessment of Export Diversification-Augmented Models", *Environmental Monitoring and Assessment*, Vol. 194 No. 414, pp.1-35.

Johansen, S. (1988), "Statistical Analysis of Cointegration Vectors", *Journal of Economic Dynamics and Control*, Vol. 12 No. 2-3, pp.231–254.

Kao, C. and Chiang, M. H. (2001), "On the estimation and inference of a cointegrated regression in panel data", Baltagi, B. H. Fomby, T. B. and Carter, H. R. (Ed.s), *Nonstationary Panels, Panel Cointegration, and Dynamic Panels*, Emerald Group Publishing Limited, Bingley, pp. 179-222.

Kuznets, S. (1955), "Economic Growth and Income Inequality", *The American Economic Review*, Vol. 45 No. 1, pp. 1-28.

Lee, H. B. (2008,) "Using the Chow Test to Analyze Regression Discontinuiti", *Tutorials in Quantitative Methods for Psychology*, Vol. 4 No. 2, pp.46-50.

Levin, A. Lin, C. and Chu, C. J. (2002), "Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties", *Journal of Econometrics*, Vol. 108 No. 1, pp. 1-24.

Mark, N. C. and Sul, D. (2003), "Cointegration Vector Estimation by Panel DOLS and Long-run Money Demand", *Oxford Bulletin of Economics and Statistics*, Vol. 65 No. 5, pp. 655-680.

Melo-Velandia, L. F. León, J. J. and Saboyá, D. (2015), "Cointegration Vector Estimation by DOLS for a Three-Dimensional Panel", *Revista Colombiana de Estadística*, Vol. 38 No. 1, pp. 45-73.

Mishra, M. K. (2020), "The Kuznets Curve for the Sustainable Environment and Economic Growth", Working Paper, Leibniz Information Centre for Economic, Hamburg.

Neal, T. (2014), "Panel Cointegration Analysis with Xtpedroni", *The Stata Journal*, Vol. 14 No. 3, pp. 684–692.

OECD. (2022), "Green Growth and Sustainable Development", available at: https://www.oecd.org/greengrowth/ (accessed 15 January 2023)

Pablo, C. (2010), "Dynamic OLS Estimation of the U.S. Import Demand for Mexican Crude oil", MPRA Paper No. 30608, Munich Personal RePEc Archive, Universität München, München, March.

Pedroni, P. (1999), "Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors", *Oxford Bulletin of Economics and Statistics*, Vol. 61, pp. 653–670.

Phillips, P. C.B. and Perron, P. (1988), "Testing for a Unit Root in Time Series Regression", *Biometrika*, Vol. 75 No. 2, pp.335-346.

Raffalovich, L. E. and Chung, R. (2014), "Models for Pooled Time-Series Cross-Section Data", *International Journal of Conflict and Violence*, Vol. 8 No. 2, pp. 200-221.

Schmidheiny, K. (2011), "Panel Data: Fixed and Random Effects", *Short Guides to Micro econometrics*, Vol. 7 No. 1, pp.2-7.

Shuai, C. Chen, X. Shen, L. and Jiao, L. (2017), "The Turning Points of Carbon Kuznets Curve: Evidences from Panel and Time-Series Data of 164 Countries", *Journal of Cleaner Production*, Vol. 162, pp.1031-1047.

Sunde, T. (2018), "Revisiting the Environmental Kuznets Curve and the Role of Energy Consumption: The Case of Namibia", MPRA Paper No. 86507, Munich Personal RePEc Archive, Universität München, München, 10 January.

Toyoshima, Y. and Hamori, S. (2011), "Panel Cointegration Analysis of the Fisher Effect: Evidence from the US, the UK, and Japan", *Economics Bulletin*, Vol. 31 No. 3, pp. 2674-2682.

World Bank. (2023), "World Development Indicators", available at: https://databank.worldbank.org/source/world-development-indicators, (accessed 19 March 2023)

Xu, B. Wennersten, R. Nils, B. and Brandt, N. (2012), "A Projected Turning Point in China's CO2 Emissions - an Environmental Kuznets Curve Analysis", *International Journal of Global Warming*, Vol. 4 No. 3-4, pp. 317-329.

Yazgan, S. Marangoz, C. and Bulut, E. (2022), "The Turning Point of Regional Deindustrialization in the U.S.: Evidence from Panel and Time-Series Data", *Structural Change and Economic Dynamics*, Vol. 61, pp. 294-304.

Zaekhan, N. and Nachrowi, D. (2012), "The Impact of Renewable Energy and GDP Per Capita on Carbon Dioxide Emission in the G-20 Countries", *Economics and Finance in Indonesia*, Vol. 60 No. 2, pp. 145-174.

Zulfikar, R. (2018)," Estimation Model and Selection Method of Panel Data Regression: An Overview of Common Effect, Fixed Effect, and Random Effect Model", available at: https://ideas.repec.org/p/osf/inarxi/9qe2b.html, (accessed 15 May 2023).