Effects of energy consumption, economic growth and population growth on carbon dioxide emissions: a dynamic approach for African economies (1990-2011)

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Effects of Energy Consumption, Economic Growth and Population Growth on Carbon Dioxide Emissions: A Dynamic Approach for African Economies (1990-2011)

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Abstract: *It has been established fact that growing energy use, specifically in the emerging economies, is associated with adverse economic, climatic and ecological effects through carbon emissions. In this regard, the study seeks to analyze the dynamics of energy consumption, economic growth and population growth on carbon dioxide emissions using panel data (1990-2011) for 9 leading African economies (including Nigeria, South Africa, Egypt, Algeria, Angola, Morocco, Sudan, Kenya, and Ethiopia respectively) based on 2014 World Bank ranking.. To achieve its objectives the study employed panel data techniques such as IPS (1997) panel unit-root test, Pedroni (1997, 1999, and 2000) panel co-integration test, Kao and Chian (2000) panel dynamic least squares (DOLS) model, and Dumitrescu-Hurlin (2012) panel causality test. The results indicated that energy consumption is the most important factor contributing to environmental pollutions and that the African economy is very much unlikely to attain EKC turning point in the long-run. The paper recommends that Africa's energy policy (specifically the panel's energy policy) should be geared towards improving energy consumption efficiency rather than reducing energy consumption so as not to adversely affect development.*

Keywords: Energy Consumption, Economic Growth, Population Growth, Carbon Dioxide Emissions, Dynamic OLS Panel Model

1.0. BACKGROUND TO THE STUDY

Climate change has, over the past two decades, been attracting the attention of the global community, dominating and re-directing international policy debate and consequently posing challenges to economic growth and development. This structural change in policy was pointed out by Arrow et al. (1995) and further popularized by Ayres et al. (2013) in which they stressed that climate policy through carbon pricing will cause much pressure on economic growth and may well mean that past rates of growth are not feasible in the future, thus indicating conflict between environmental and economic policies.

In this regard, climate change demands that the global community rethink the relationship between energy and environment in particular and the relationships among environment-related economic variables (including energy consumption, economic growth, population growth and carbon dioxide emissions) in general.

In sub-Saharan Africa, for instance, economic growth has been associated with increased energy demand leading to substantial energy challenges. Africa Progress Report (APR; 2015) reveals that there are still over 600 million people without access to modern energy. It emphasizes the fact that sub-Saharan Africa's electricity consumption is less than that of Spain and that base on the current trend it will take until 2080 to provide access to electricity to every African.

Since 2000, energy demand in the sub-Saharan Africa has increased by half reaching 570 million metric tons of oil equivalent (MMtoe) in 2012 (EIA; 2016), but the figure account only for 4per cent of the World total. Although this growth in energy demand has out-paced that of other regions leading to increased grid-based power generation from around 68giga watts (GW) in 2000 to 90GW in 2012, it has lagged behind the economic expansion, as in many countries it was led by sectors with relatively low-energy intensity such as tourism and agriculture. However, the irony remains that irrespective of the rapidly growing energy use in the emerging economies (Africa inclusive), the developed economies still use almost five times, as much energy per capita, World Development Index (WDI, 2013).

Economic growth and energy consumption are accompanied by environmental degradation in both developed and developing economies, Narayan and Narayan (2010). In 2011, Africa as whole emits only 3.4per cent of the World total emissions of 32,154.99mmtns of carbon (EIA; 2016). In fact, the same source reported that the sub-Saharan Africa accounts for only a very small share of cumulative historical energy-related carbon emissions; in the 1900 to 2012 periods the region was responsible for only 1.8per cent of the global total. Nevertheless, Africa Progress Report (2015) indicates that an estimated 300,000 children under the age of five die annually in Africa due to household air pollution from the use of biomass fuel for cooking.

Further, joint report by PBL Netherlands Environmental Assessment Agency and European Commission Joint Research Centre (JRC), titled "Trends in Global CO_2 Emissions 2013 Report", concluded that the trend in the global CO_2 emissions mainly reflects energy-related human activities which, over the past decades, were determined by economic growth, particularly in the emerging countries. This implies that it is the synergy among energy consumption, economic growth and population growth that continues to contribute to the increasing global carbon dioxide emissions. As such this study investigates the dynamic effects of the three key factors on carbon dioxide emissions.

The main objective of the study is to analyze the long-run dynamic effects of energy consumption, population growth and economic growth on CO_2 emissions using panel data (1990-

2011) for 9 leading African economies (including; Nigeria, South Africa, Egypt, Algeria, Angola, Morocco, Sudan, Kenya, and Ethiopia respectively) based on World Bank ranking, 2014. The specific objectives are:

I- To test the long-run validity of environmental Kuznets curve (EKC) hypothesis for the panel of interest.

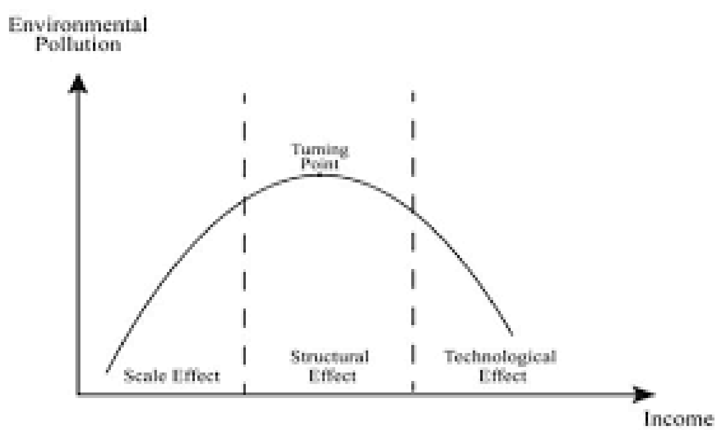
II- To check for the direction of causality between economic growth and energy consumption.

2.0. Theoretical Frame-work and Empirical Literature

Environmental function (i.e. the link between economy and environment) is commonly examined using environmental Kuznets curve (EKC) hypothesis which postulates inverted U-shaped relationship between environmental pollution and economic growth. It was named after Kuznets (1955) and introduced and popularized by Grossmann and Krueger (1991).

The inverted U-shaped curve indicates how pollution increases as the share of agriculture goes down and that of industry goes up during the early stage of development. However, as economic development progresses and income grows, the share of industry too will go down as that of services goes up. This implies that inter-sector changes are likely to favor less polluting sectors (e.g. Janicke, Blinder, and Monch; 1997, as cited in Stern; 2003) as indicted in figure 1.1

Figure 1.1: Environmental Kuznets curve



Like with most other fields of research, empirical literature on the environmental function remains inconclusive. While Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992), Mor and Jindal (2012) supported the EKC hypothesis, Arouri et al. (2012), Mohammadi (2012), Klasen and Nestmann (2001), Coal and Neumayer (2005) and Arrow et al. (1995) have found poor evidence with respect to EKC hypothesis.

Apart from Johnson (2015), Muftau, Iyoboyi and Ademola (2014), Arouri et al. (2014), Fawowe (2012), and Chali et al. (2010) none of the panel based studies, reviewed in this work, is completely on African economies. Noting the fact that Farhani et al. (2013), Mohammed and Seghir (2013), Arouri et al. (2012), Adhikari and Chen (2012), and Demette and Seghir (2011) are partly on Africa. While the seminal paper by Kraft and Kraft (1978) believe to be the pioneer empirical work in the area of interest, Robert U. Ayres and Benjamin Warr can be classified as the leading authors in the field of energy economics especially with respect to production function based approach to energy and economy relations.

It is also noticed that Muhammad Shahbaz, Mohammed Arouri, Farhani Sahbi, among others are playing the leading role in the literature on the triangular relationship among CO_2 emissions, energy, and economic growth specifically for Asian economies. Shahidan et al. (2013) was found to have examined the simultaneous links among population growth, energy consumption and economic growth. Shahbaz et al. (2015) examine the relations among economic growth, population growth, CO_2 emissions and globalization for Australia. Only Ara et al. (2015) investigate the dynamics of economic growth, energy consumption and population growth on carbon emissions in Malaysia.

It can, therefore, be concluded that the reviewed studies have not investigated the possibility of attaining EKC turning point in long-runs specifically for African economies. As a matter of fact, identifying the EKC turning point will serve as important inputs in making environmentally clean and economically viable policies for greener and sustainable growth and development.

2.1 Energy Consumption, Economic Growth, Population Growth and Carbon Emissions in Africa

2.1.1 Energy Consumption in Africa

Africa’s energy mix is dominated by bioenergy which is accounting for more than 60 per cent of its total energy consumption. This development is largely driven by traditional consumption of biomass (specifically charcoal) for cooking. The share of energy consumption in end-user sector account for one-third of the total energy consumption in the residential sector compared with just 20per cent across the OECD. The share in the end-user sectors is much lower than in other World regions, reflecting very low availability of energy services; transport accounting for only 11per cent of final energy consumption, and productive uses such as agriculture, industry, and services together accounting for only 21per cent (IEA; 2014).

According to the same source, Africa's energy consumption per capita is, on average, one-third of the World average (2.1tonnes of oil equivalent [toe] per capita) and only half of the level of developing Asia. The report pointed out large differences in per capita energy consumption between urban and rural areas across the sub-Saharan Africa. It indicates that urban residents are more likely to be wealthier and as a consequence often enjoy better access to energy either through the grid or the use of back-up generator.

Africa's primary energy demand stood at 739milliontoe in 2012, of which North Africa accounted for 23 per cent (IEA; 2014). Since 2000, energy demand in sub-Saharan Africa have increased by half reaching 570Mtoe in 2012 which driven the grid-based power generation capacity in Africa to have increased from around 68giga watts (GW) in 2000 to 90GW in 2012, with South Africa alone accounting for about half of the total.

2.1.2 Economic Growth in Africa

In spite of the fact that African economies are largely un-modernized with agriculture remains a large sector in many of the Africa's economies, accounting for more than 20per cent of regional GDP (compared with a 6per cent globally) and mining still playing significant role both in providing employment and foreign exchange. The African economy has more than double in since 2000 to reach $2.7 trillion in 2013. But the economic output of the whole of African countries (940 million people) remains comparatively lower than that of Germany (82 million people) in the same year 2013, IEA (2014).

However, rapid population growth of about 45per cent has dampens the growth of per capita GDP in Africa. This suggests that even though the increasing per capita income across Africa has contributed in reducing the total share of population living in absolute poverty form around 56per cent in 1990 to below 49per cent in 2000, the rapid population growth meant that the number of people still living in absolute poverty has actually increased, World Bank (2014).

Nigeria and South Africa are the largest economies by far, together accounting for more than half of the sub-Saharan Africa economy. The two largest economies in Africa are, as indicated by the World Bank ranking 2014, followed by Egypt, Algeria, Angola, Morocco, Sudan, Kenya, and Ethiopia respectively.

2.1.3 Population Growth in Africa

According to UN (2015), as the World population added approximately one billion people in the span of the last twelve years reaching a total of 7.3 billion people as of mid-2015, Africa's economy constituted 16per cent of the total (1.2 billion people). Sixty per cent of the global population lives in Asia (4.4), 10per cent in Europe (738 million), 9per cent in Latin America and Caribbean (634 million), and the remaining 5per cent in North America (358 million) and Oceania (39 million).

Africa's population has increased by 270 million people between 2000 to 2013 and although this development brings about rising working-age population especially in West and East Africa, it magnifies many existing development challenges such as rising energy demand in addition to the fact that the population of sub-Saharan Africa receives less than five years of schooling on average (UNDP, 2013; as cited in IEA; 2014), implying the fact that level of education and skills are likely to remain a key challenge.

2.1.4 Carbon Dioxide Emissions in Africa

Africa emits only 3.4percent of the World total emissions of 32,154.99 million metric tons (MMtns) of carbon emissions in 2011, compared to 44.5per cent emits by Asia and Oceania combine and 20.16per cent by North America, 13.52per cent by Europe, 7.94per cent by Eurasia, 6.09per cent by Middle East and 4.15per cent by Central and South America combined, data from U. S. Energy Information Administration (EIA, 2016) have shown.

Further, the data indicates that as the global emissions increased by 74.43percent in 2011 compared to the 1980 emissions level, Africa's carbon emissions increased by 65.44per cent from 1980 to 2000 and by 117.96per cent by 2011. Comparatively, carbon emissions increased by 18percent from 1980 to 2011 in North American, and increased by about 300per cent (299.29per cent) in the Middle East. However, the emissions levels have decreased within the same period by 7.09per cent and 45.48per cent in Europe and Eurasia respectively.

In addition, the fossil-fuel carbon emissions are relatively low both in absolute and per capita terms in Africa. The total emissions have increased twelve fold since 1950 reaching 311mmtns of carbon in 2008, but still less than the emissions for some single countries including Mainland China, United State of America, India, Russia and Japan. Although per capita emissions in 2008 (0.3 metric tons of carbon) was three times those of 1950, they were only 6.6per cent of North America within the same period (Boden, Marland and Andres; 2011). Very few African countries are accounting for this growth in carbon emissions from fossil-fuel and cement production; South Africa 38per cent, with 46per cent coming from Egypt, Algeria, Nigeria, Libya and Morocco as indicated by the same study.

3.0. Data and Methods

The study employed annual panel (time-series) data on the four key environment-related economic variables including CO_2 emissions (CO_2E), energy consumption (ECON), population growth (POPU) and economic growth (RGDP).

The data series for RGDP, ECON, POPU and CO_2E are sourced from World Development Indicators; World Bank Data Bank.

3.1. Variables Measurement

CO2E is a proxy of environmental pollutions specifically those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.

RGDP is a proxy of economic growth using data series on gross domestic product (GDP) at international constant prices in US $ in Purchasing Power Parity (PPP).

ECON refers to energy use (kt of oil equivalent) particularly before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.

POPU refers to total population based on the de facto definition of population, which counts all residents regardless of legal status or citizenship, except for refugees not permanently settled in the country of asylum as they are generally considered part of the population of their country of origin.

3.2. Panel Data Models Specification

The Im, Pesaran and Shin (IPS) panel unit-root test

Im, Pesaran and Shin (1997); extended LL (1992) test allowing for heterogeneity on the *P* i.e. the coefficient of $Y_{i,t-1}$ using a testing technic that relies on computing the average of individual unit-root test statistics. The test provides separate estimations for each cross-section and allow for different specifications of the parametric values, the residual variance and the lag lengths. It is express as:

$$\Delta Y_{i,t} = a_i + p_i Y_{i,t-1} + \sum_{k=1}^{n} \Phi_k \Delta Y_{i,t-k} + \delta_i t + \theta_t + \mu_{i,t} \text{ ……………………… (eq.3.3.1.2)}$$

The null and alternative hypotheses are formulated as:

$H_0 : p_i = 0$ for all i

$H_0 : p_i < 0$ for at least one i

Unlike LLC test which presumes that all series are stationary under the alternative hypothesis, IPS assumes that all series are non-stationary under the null against an alternative that fractions of the series in the panel are assumed to be stationary. Nevertheless, IPS (1997) formulated their model under the restrictive assumption of a balanced panel, thus a panel with equal number of T for all the cross-section units.

The Pedroni (1997, 1999 and 2000) panel co-integration test

To allow for heterogeneity across the cross-sections, Pedroni (1997, 1999 and 2000) proposes combination of tests for co-integration in the panel data model which differs from McCoskey and Kao (M&K) in two respects. These are in assuming trends for the cross-sections and in consideration of null hypothesis of no co-integration. Thus, unlike M&K (1998) test that is restricted to simple two variables case, Pedroni's test allow for multiple regressors and for heterogeneity in the errors across cross-section units. He proposed the following panel co-integration model:

$$Y_{i,t} = \alpha_i + \delta_t + \sum_{m=1}^{m} \beta_{m1} X_{mi,t} + \mu_{i,t} \text{ ………………………… (eq.3.3.2.3)}$$

The test involves seven different co-integrating statistics classified in to two broad categories:

(i) Consists of four different test statistics based on 'within' dimension which include;
   a) The panel V statistic
   b) The panel *p* statistic
   c) The panel *t* statistic (non- parametric)
   d) The panel *t* statistic parameter)

(ii) Includes three test statistics based on 'between' dimension as follows:
   a) The group *p* statistic (parametric)
   b) The group *t* statistic (non-parametric)
   c) The group *t* statistic (parametric)

Its, therefore, pertinent to note that one major drawback of the Pedroni's test is the restrictive a priori assumption of a unique co-integrating vector.

Panel dynamic least squares (DOLS) estimator

Kao and Chiang (2000) consider the following panel model:

$$Y_{it} = X'_{it}\beta + Z'_{it}\gamma + \mu_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(eq.3.3.3.1)}$$

Where: $\{Y_{it}\}$ are 1x1, β is a K x 1 vector of the slope parameter, Z_{it} is the deterministic component and $\{\mu_{it}\}$ are the stationary disturbance terms, $\{X'_{it}\}$ are k x 1 integrated processes of order one for all i, and

$$X_{it} = X_{I,t-1} + \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(eq.3.3.3.2)}$$

The model maintain the assumption of cross-section independence

In investigating finite sample properties of OLS, FMOLS and DOLS estimators, Kao and Chiang arrived at three conclusions.

i) The OLS estimator has non-negligible bias in the finite samples
ii) FMOLS does not improve upon the OLS estimator
iii) DOLS estimator was found more promising compared to both OLS and FMOLS estimators specifically for co-integrating panel regressors.

Dumitrescu-Hurlin (2012) Panel Granger causality test

Causality is computed by running bivariate regressions which in panel data context take the following form:

$$Y_{i,t} = \alpha_{o,i} + \alpha_{1,i}\, y_{i,t-1} + \ldots + \alpha_{1,i}\, y_{i,t-1} + \beta_{1,i}\, x_{i,t-1} + \ldots + \beta_{1,i} x_{i,t-1} + \varepsilon_{i,t} \ldots\ldots\ldots\ldots \text{(eq.3.3.4.1)}$$

$$X_{i,t} = \alpha_{o,i} + \alpha_{1,i}\, x_{i,t-1} + \ldots + \alpha_{1,i}\, x_{i,t-1} + \beta_{1,i}\, y_{i,t-1} + \ldots + \beta_{1,i} y_{i,t-1} + \varepsilon_{i,t} \ldots\ldots\ldots\ldots \text{(eq.3.3.4.2)}$$

Where: *t* denotes the time period dimension of the panel, and *I* denotes the cross-section dimension.

Panel causality tests are said to differ on their assumptions about the heterogeneity of the coefficients across cross-sections. The simple test treat the panel data as one large stacked set of data assuming that all coefficients are same across all cross-sections. Nevertheless, Dumitrescu-

Hurlin (2012), as cited in E-views 9 User Guide II, developed a test used to investigate for causation while allowing all coefficients to be different across cross-sections.

$\alpha_{o,i} \neq \alpha_{o,j}$, $\alpha_{1,i} \neq \alpha_{1,j}$….. $\alpha_{1,i} \neq \alpha_{1,j}$, $\forall_{i,j}$

$\beta_{1,i} \neq \beta_{1,j}$,….., $\beta_{1,i} \neq \beta_{1,j}$ $\forall_{i,j}$

Dumitrescu and Hurlin have shown that the standardized version of this statistic (i.e. zbar statistic) appropriately weighted in unbalanced panels, and follow a standard normal distribution.

4.0. RESULTS/FINDINGS

4.1. Panel Unit-Root Results

Table 1: IPS Individual unit-root process

Variable	W-Statistic	Probability	Order of Integration
CO_2E	10.8070***	0.0000	I(1)
ECON	8.46597***	0.0000	I(1)
RGDP	2.50628***	0.0061	I(1)
POPU	2.19706**	0.0140	I(1)

Note: ***and** indicate rejection of null hypothesis at 1% and 5% levels of significance respectively

The table displays the result of the unit-root test using IPS individual unit-root process with a view to allowing for heteroskedasticity in the individual cross-sections that constitute the panel. All the series in the model were found non-stationary at level, but integrated at the first difference. This calls for the adoption of panel co-integration test with a view to confirming the existence of long-run association among the variables under investigation.

4.2. Pedroni's Panel Residual Co-integration Test:

Table 2: Series CO2E, ECON, RGDP and POPU

Null Hypothesis: No Co-integration				
Within Dimension	Statistics	Prob.	Weighted Statistic	Prob.
Panel V-Statistic	1.911655**	0.0280	-1.072780	0.8583
Panel rho-Statistic	-3.609090***	0.0002	-1.557407	0.0597
Panel pp-Statistic	-7.743743***	0.0000	-4.388169***	0.0000
Panel ADF-Statistic	-7.725621***	0.0000	-5.282656***	0.0000

Between Dimension	Statistic	Prob.
Group rho-Statistic	0.067700	0.5270
Group pp- Statistic	-2.824397***	0.0024
Group ADF-Statistic	-4.140204***	0.0000

Note: ***and** indicate rejection of null hypothesis at 1% and 5% levels of significance respectively

Table 2 above provides several Pedroni panel co-integration tests statistics which evaluate the null hypotheses against both homogeneous and heterogeneous alternatives. It shows that eight of the eleven statistics reject the null hypothesis at the conventional level of significance of 5%, suggesting co-integration among the variables under study. This, however, calls for the application of panel co-integrating estimations method such as Ordinary Least Squares (OLS), Fully Modified Ordinary Least Squares (FMOLS) or Dynamic Ordinary Least Squares (DOLS). As noted in section three, the most consistent and suitable method for co-integrated panel is DOLS and as such this study employ same in estimating the parameters of the co-integrated equation(s).

4.3. DOLS Estimation Result: Co-integrating Estimation

Table 3: Dependent variable CO_2E

Variable	Cefficient	Std. Error	t-Statistic	Prob.
ECON	6.707432***	1.058401	6.337324	0.0000
RGDP	1.59E-07**	7.47E-08	2.135069	0.0403
POPU	0.053024***	0.003480	15.23508	0.0000
Diagnostics test				
		JB Statistics	Prob.	
JB Normality Test		3.248214	0.197088	

Note: ***and** indicate rejection of null hypothesis at 1% and 5% levels of significance respectively

The DOLS estimation, as shown in table 3, included 9 cross-section units and 22 periods using panel data series from 1990-2011. In the method option, Group Mean is selected with constant and trend variable as the cross-section specific trend regressors. Pedroni (1990), as cited in E-views 9 User Guide II, noted that the Group Mean estimator offers the desirable property of providing consistent estimates of the sample mean of the co-integrating vectors. The coefficient covariance are computed using the default settings and the long-run covariance are based on auto-

Schwarz maximum lag specification and Bartlett kernel option with Newey-West automatic bandwidth and lag length for individual covariance.

The result shows that all the regressors including ECON, RGDP, and POPU are positive functions and significant determinants of CO_2E in the long-run at the conventional 5% level of significance. The coefficient of ECON indicates that a unit change in energy consumption (i.e. increase by a kiloton of oil equivalent), will lead, on average, to increase in the pollution level by about 6,707 kilo tons of carbon emissions in the atmosphere. Similarly, a unit change in economic growth (i.e. increase by a $ million international dollar in purchasing power parity), will lead, on average, to increase in the pollution level by 0.000159 kilo tons of carbon emissions. Further, a unit change in population (i.e. increase in the population by a million people), will lead, on average, to increase in the pollution level by about 53.02 kilo tons in the long-run.

4.4. Panel Causality Test

Table 4: Pairwise Dumitrescu-Hurlin panel causality test result

Lag:2			
Null Hypotheses	W-Statistic	Zbar-Statistic	Prob.
ECON does not homogeneously cause CO_2E	5.00523	3.00305	0.0027
CO_2E does not homogeneously cause ECON	2.62078	0.34854	0.7274
RGDP does not homogeneously cause CO_2E	4.84067	2.81984	0.0048
CO_2E does not homogeneously cause RGDP	3.99454	1.87789	0.0604
POPU does not homogeneously cause CO_2E	8.74651	7.16803	8.E-13
CO_2E does not homogeneously cause POPU	11.0528	9.73552	0.0000
POPU does not homogeneously cause ECON	22.7824	22.7935	0.0000
ECON does not homogeneously cause POPU	9.79948	8.34026	0.0000
RGDP does not homogeneously cause ECON	6.12180	4.24607	2.E-05
ECON does not homogeneously cause RGDP	7.38889	5.65666	2.E-08
RGDP does not homogeneously cause POPU	65.8234	70.7091	0.0000
POPU does not homogeneously cause RGDP	7.29121	5.54792	3.E-08

The result of the Dumitrescu-Hurlin tests, presented in table 4 above, rejects the null that ECON does not homogeneously Granger cause CO_2E, but do not direct in the opposite direction. Similarly, it rejects the null that RGDP does not homogeneously cause CO_2E but accept the null in the opposite direction. The test also rejects the null that POPU does not homogeneously cause CO_2E as well as in the opposite direction, thus, indicating a two-way homogeneous causality. It again shows that there is bi-directional causality between POPU and ECON, RGDP and ECON as well as between RGDP and POPU.

5.0. Conclusion and policy implications

The DOLS regression result suggests that energy consumption, population growth and economic growth are important contributing factors to carbon emissions in the African economy, specifically for the panel under consideration. The result supports the findings of Ara et al (2015), Farhani et al (2013), Shahbaz (2012) and Arouri et al (2012) for energy consumption and growth. Its, however, evident that energy consumption is the most important factor contributing to the increasing concentration of carbon dioxide in the atmosphere which continue to contributes to the global warming. This might be a reason why the developed economies continued to mount pressure persistently on the developing economies that they should choose between growth and low-carbon development either through cut in energy consumption or switching to low-carbon energy source like natural gas. Alternative, the developing economies could consider improving upon energy efficiency with a view to reducing energy consumption per unit of output.

However, none of these options seem feasible for Africa because different fossil fuels do not only vary in their carbon content and in turn the amount of carbon emitted per unit of energy produced but also in the units of energy produced. For instance, for the same amount of energy produced, natural gas produces about half and petroleum produces about three-fourth of the amount produced by coal. Nevertheless, relatively low-carbon energy attracts higher cost and produces low energy in comparative terms. As such, for Africa to meet its growing demand for energy, specifically electricity, switching to low-carbon energy could only be an option in the long-run, when the required amount of energy is met.

Again, if the goal is to cut energy consumption, improving energy consumption efficiency would only resulted in the "**rebound effect**" there by making the targeted objective far from being achieved. This is because, improving energy efficiency works to increase, rather than decreasing energy consumption. Thus, by reducing unit cost of goods, improved efficiency will in turn increases demand for the product which will ultimately increase the amount of energy consumption while meeting the rising demand.

Further, Africa Progress Panel, in its 2015 Report, noted that about 621 million people lack access to electricity in the Sub-Saharan Africa, stressing the fact that the electricity demand is increasing. As such, any attempt at reducing energy consumption, especially electricity, would aggravate the power shortages that have been retarding Africa's development efforts. Perhaps, it was noted earlier in this research that Africa's electricity consumption is less than that of Spain and based on the current trends it will take until 2080 for every African to have access to electricity (IEA; 2014).

It is, therefore, pertinent to note that any policy instrument designed to achieve targeted reduction in carbon emissions should only be entertain if it allow for continued development in all regions and countries thereby facilitating unimpeded industrialization in developing countries, specifically in Africa.

But, the fact is that the economies are yet to be fully industrialized, mostly relying on primary production and very much unlikely to attain the EKC turning point. The panel's energy supply has been either stagnant or increasing in such a way that it might hardly meet up with the growing energy demand, leading to decline in per capita energy consumption which will consequently reduce per capita emissions.

The unidirectional causality running from energy consumption to carbon dioxide emissions confirm the findings of Mor and Jindal (2012) and Farhani, Shahbaz and Arouri (2013) and the bidirectional causality between energy consumption and economic growth imply that energy consumption is critical to African economy despite the major role it plays in the global warming. This suggests that Africa should utilize fully its energy resources in meeting its current energy demand while making preparation for solid and sustainable foundation for a comparatively low-carbon energy infrastructure in the long-run.

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