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Article

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Is there Cointegration between Renewable Energy and Economic Growth in Selected Sub-saharan African Counries?

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ABSTRACT

Globally, much attention is being paid to the environment due to the negative effects of environmental degradation on human lives resulting from population growth for instance. With a growing population in Africa it is only natural that the demand for energy for various activities would continue to grow. At present, most of the energy being produced and consumed in Sub-Saharan Africa is derived from non-renewable sources which have triggered calls to shift attention to renewable energy sources. This situation raises some pertinent research questions. Is there a relationship between renewable energy and economic growth in some selected sub-Saharan African countries? Through a panel co-integration approach, the findings revealed that there is a long-run relationship between renewable energy and economic growth in the selected Sub-Saharan African countries. This calls for the implementation of public policies towards the promotion of renewable energies in Africa to combat the negative effects of carbon emissions.

Keywords: Renewable Energy, Economic Growth, Panel Data, Co-integration, Sub-Saharan Africa
JEL Classifications: K32, P18, Q28

1. INTRODUCTION

Energy has been recognised to be an essential input used in the production process. Increased use of energy has been discovered to contribute to economic growth and overall development of the society (Bozkurt and Akan, 2014). The significance of energy in the growth and development of a country cannot be overemphasised as numerous studies have proven that energy consumption engenders economic growth (Nondo and Kahsai, 2009; Tiwari, 2011; IRENA, 2013; Arouri et al., 2014; Senturk and Sataf, 2015). However, despite its advantage to economic performance, the increased use of energy has not come without some opportunity costs.

The phenomena of climate change has led to increased attention in alternative sources of energy that are environment-friendly. The climate change condition has worsened due to both human and industrial activities that have led to the increase in carbon dioxide (CO_2) emissions. Though these human and industrial activities have helped to raise the level of economic performance, they have negatively affected the environment (Kareem et al., 2012; Alege et al., 2015; Mitic et al., 2017; Boontome et al., 2017; Belaid and Youssef, 2017; Balsalobre-Lorente et al., 2018). Thus, a dilemma poses itself. Do we stop human and industrial activities so as to protect the environment? The answer is, we cannot because doing so would adversely affect economic performance and human welfare. The way out of this, is to consider alternative sources of energy that are environment-friendly and that could be used for human and industrial activities. Renewable energy provides this alternative option.

Renewable energy refers to the form of energy that is obtained from sources that are natural and thus, constantly replenishes itself (OXFAM, 2017). Sources of renewable energy include energy from solar, wind, hydropower and biomass resources (JRC, 2011). The benefits to be gained from increased use of renewable energy are numerous. IRENA (2016) identify that attainment of climate goals, creation of employment opportunities, economic growth, improved human welfare and new trade opportunities are some of the benefits of using renewable energy rather than non-renewable energy.

Despite that currently, Sub-Saharan Africa is accountable for about 2% of the total CO_2 emissions in the world, this share is expected to grow by about 50% by 2040 (UNFCCC, 2016; IEA, 2014; Sy, 2016). The reason for this has been attributed to the expected explosion in the continent's population in only a few decades from now. The current population of Africa represents 13% of the world's population and by 2040, the population is expected to be one-fifth (20%) of the entire world's population (IEA, 2014). By 2050, most of the population growth is expected to occur in Africa (EIA, 2017; UN, 2017). In addition, Africa's economy is likely to expand at an impressive rate of between 4 and 6% over the next 13 years (IEA, 2014). With an expected rise in population and economic growth, energy demand is expected to rise as well. It is, therefore, no surprise that much attention has been placed on renewable energy, economic growth and carbon emissions.

Therefore, the objective of this study is to determine whether a long run relationship exists between renewable energy and economic growth for selected Sub-Saharan African economies. The rest of this paper is structured as follows: Section 2 presents the literature review. The methodology is presented in Section 3. The findings and discussion of the results are documented in Sections 4 and 5 contains the conclusions of the paper.

2. LITERATURE REVIEW

A lot of research have been carried out to determine the nature of association that exists between energy consumption and economic growth. Some of the studies done in this area are country-specific studies while others are panel studies. However, the results have been inconclusive. Some of the studies align with the "growth hypothesis" where energy consumption causes economic growth. Some other studies align with the "conservation hypothesis" which occurs when economic growth causes energy consumption. Another category is the "feedback hypothesis" which exists in the case of a two-way causality between energy consumption and economic growth. The "neutrality hypothesis" is the final category which occurs when there is no causality flowing between energy consumption and economic growth. This paper envisages to align to one of these propositions and thus, contribute to the existing literature.

In examining the link between different sources of energy and economic growth in Brazil, Pao and Fu (2013) made use of annual data spanning 31 years (1980-2010). The results reflected that renewable energy bears both a positive effect and a causal relationship with the growth of the economy. The authors suggested that policy makers could adopt more incentives in order to encourage the use of renewable energy sources in Brazil. Similarly, Leitao (2014) investigated the relationship amongst economic growth, carbon emissions, renewable energy and globalisation in Portugal. To this end, the author employed a variety of econometric tests including the ordinary least squares, the generalized method of moments and the Granger causality tests. Carbon emissions, renewable energy and globalisation were found to positively affect economic growth. In addition, the growth hypothesis was confirmed.

Bildirici and Ozaksoy (2015), on the other hand, investigated the relationship between woody biomass energy consumption and economic growth for 8 Sub-Saharan African countries from 1980-2013. The authors made use of the autoregressive distributed lag (ARDL) model for this purpose. The findings from their study revealed that the growth hypothesis held true for Angola, Niger and Guinea-Bissau. The conservation hypothesis was confirmed for seychelles while evidence from Nigeria, Benin, South Africa and Mauritania confirmed the feedback hypothesis. On the contrary, Taghvaee et al. (2017) supported the neutrality hypothesis for Iran. The authors made use of the ARDL model while utilizing annual data spanning a period of 32 years (1981-2012). The authors attributed the large use of non-renewable energies as the reason why renewable energy exerted a negligible effect on economic growth in Iran. They suggested that policy makers should encourage the increased use of renewable energy.

Thombs (2017) made use of a panel of 129 countries so as to determine the relationship between renewable energy and economic growth. Diverse findings were discovered for countries with different income groups. For low-income countries, renewable consumption is found to have its largest negative effect on carbon emissions while for high-income countries, the effect was found to be little. In their study of 28 European Union countries from 2003 to 2014, Armeanu et al. (2017) confirmed the growth hypothesis both in the long and short runs. The same finding was also recorded when renewable energy was delineated into its different types.

Kocak and Sarkgunesi (2017) studies the interaction between renewable energy and economic growth in 9 Black Sea and Balkan countries. Different results were obtained for each of the different countries. Most of the countries supported the growth hypothesis while the rest supported the feedback hypothesis except for one country which aligned with the neutrality hypothesis. However, for a panel of 11 net oil-importing countries in the Middle East and North Africa (MENA), Kahia et al. (2017) studied the relationship amongst the disaggregated energy consumption and economic growth. They utilised yearly data ranging from 1980 to 2012. The feedback hypothesis was confirmed for both types of energy in both the long and short runs. Similarly, the result obtained by Lin and Moubarak (2014) for China showed evidence for the feedback. Other studies that support the feedback hypothesis include Apergis and Payne (2011), Sebri and Salha (2013); Cho et al. (2015); Amri (2017); Ben Jebli et al. (2015); Troster et al. (2018).

In recent times, the attention of researchers have shifted to understanding whether the consumption of renewable energy influences the emission of greenhouse gas emissions including CO_2 emissions. Silva et al. (2012) analysed how an increasing share of renewable energy sources in electricity generation affects economic growth and carbon emissions in a panel of 4 countries. Interestingly, the authors found that an increasing share of renewable energy led to a reduction in both carbon emissions and economic growth. They recommended the adoption of renewable energy complementary policies such as demand management and energy conservation policies.

Abolhosseini et al. (2014) discovered that carbon emissions and economic growth are positively related in the EU-15. Governmentsupporting mechanisms were more effective in reducing carbon emissions. The authors insisted that economic growth was not a prerequisite for having cleaner environment. Thus, developing countries could achieve cleaner environments even without having attained high levels of economic growth. In 2015, Farhani (2015) discovered that for a group of 12 MENA countries, in the short run, there was no causal relationship amongst renewable energy consumption, economic growth and carbon emissions except for the unidirectional causality running from renewable energy consumption to carbon emissions. In the long run, however, the author discovered that unidirectional causality flowed from both carbon emissions and economic growth to renewable energy consumption.

For Thailand, Boontome et al. (2017) carried out an investigation to determine the causal relationship existing amongst types of energy consumption, CO_2 emissions and economic growth. Employing yearly data from 1971 to 2013, the authors confirmed the existence of cointegartion and causality flows from non-renewable energy consumption to CO_2 emissions. They recommended that Thailand should increase its use of renewable energy. Using Tunisian data, Brini et al. (2017) were able to investigate the link amongst renewable energy consumption, price of non-renewable energy (oil price) and economic growth. By adopting the ARDL model and using yearly data from 1980 to 2011, the authors found that there was a positive relationship between oil price and renewable energy consumption. A unidirectional relationship flowing from renewable energy consumption to the price of non-renewable energy was also discovered.

To investigate the relationship amongst CO_2 emissions, renewable energy consumption and economic growth in Tunisia, Cherni and Jouini (2017) made use of the ARDL model. The results from their study indicated that the variables were cointegrated. In addition, the study uncovered the existence of a bidirectional relationship between CO_2 emissions and economic growth. Moreso, the feedback hypothesis was confirmed. CO_2 emissions and renewable energy consumption did not have any causal relationship. Other studies that have also found that increased consumption of renewable energy reduces the level of carbon emission include York and McGee (2017) and Fotourehchi (2017).

Even though there are numerous studies that have examined the relationship amongst renewable energy, economic growth and CO_2 emissions, only a handful have considered the introduction of oil price into the mix. Oil is a key energy source in the world and its price has been unstable. High prices of oil has made oil-importing countries to seek other energy alternatives that are cheaper and more sustainable. This in turn affects the revenue of oil-exporting countries. Low oil prices produces the reverse scenario. Thus oil price becomes an important variable hen studying the renewable energy-growth- CO_2 emissions mix.

Zaghdoudi (2017) examined the relationship amongst renewable energy, oil prices, CO_2 emissions and economic growth for the OECD countries. The author made use of annual data from 1990 to 2015 and found that in these countries, an increase in the price of oil led to a reduction in CO_2 emissions. In addition, following the increased use of renewable energy,the level of CO_2 emissions was reduced. A bidirectional relationship was found between oil prices and CO_2 emissions. The author recommended that investment in cleaner energy sources should be promoted.

3. METHODOLOGY

3.1. Model Specification

The main objective of this paper is to determine the existence of a long run relationship between renewable energy and economic growth in some selected Sub-Saharan African (SSA) countries. The model follows the specification of Fatai (2014) by adopting a regression procedure where both the dependent and independent variables are expressed in their natural logarithmic form. However, our model has been extended to include both carbon emissions and crude oil prices. The model is specified in its implicit form as:

$$REE_t = f(RGDP_t, CE_t, OILP_t) \quad (1)$$

Where REE_t represents renewable energy consumption, $RGDP_t$ is the real gross domestic product, CE_t represents carbon emissions, and $OILP_t$ denotes crude oil prices.

Assuming the existence of a non-linear relationship between the dependent variable and the independent variables, the model is expressed in the explicit form as:

$$REE_t = A.RGDP_t^{a1}.CE_t^{a2}\ .OILP_t^{a3}.m_t \quad (2)$$

In order to carry out the different estimation, equation (2) is log-linearised which is represented as:

$$LnREE_t = \alpha_0+\alpha_1\ LnRGDP_t+\alpha_2 LnCE_t+\alpha_3 LnOILP_t+\mu_t \quad (3)$$

Where $LnREE_t$ denotes the logarithm function of renewable energy consumption, $LnRGDP_t$ represents the logarithm function of RGDP, $LnCE_t$ denotes the logarithm function of carbon emissions, and $LnOILP_t$ represents the logarithm function of oil prices. μ_t is the error term. The inclusion of RGDP and CE emanates from the literature that increase in total output causes the demand of energy and emissions to the environment also influcences the demand for energy, respectively (Fatai, 2014)

3.2. Estimation Technique

The econometric method applied in this paper is in three major parts: First, we follow the standard procedure of time series by testing for the presence of unit root. Given that we use a panel dataset whose analysis differs from Univariate unit root testing, we follow the approach of Alege and Osabuohien (2010); and Ogundipe et al. (2015) by using two statistics, namely Levin, Lim and Chu (LLC) and Im, Pesaran and Shin (IPS). Second, we test for panel co-integration through the use of the Engle-Granger approach and lastly, we make use of the Granger causality approach towards the observation of the direction of causality between the dependent and independent variables.

3.2.1. Panel unit root test

The panel unit root test of Levin et al. (LLC) (2002) and Im et al. (IPS) (2003) are adopted towards ascertaining the order of integration of the macroeconomic variables. According to Mitic et al. (2017), these test statistics are an annexe of the conventional Augmented Dickey Fuller (ADF) test statistics. This estimation has become popular because their asymptotic distribution is standard normal as opposed to non-normal asymptotic distribution (Nondo and Kahsai, 2017).

The LLC test depends on pooled data allowing for heterogeneity in the intercept term, while the IPS test is obtained as an average of the ADF statistics accounting for heterogeneity in both the intercept and slope terms for the cross-section units (Bildirici and Kayikci, 2016). The null hypothesis states that all series in the panel have a unit root while the alternative sates that all the series in the panel are stationary.

3.2.2. Panel co-integration

The next step of the analysis is to detect for the presence of a co-integration through the use of the Engle-Granger approach by Pedroni (1999) and the Kao (1999) extension. Pedroni (1999) method accounts for the heterogeneity by using specific parameters which are allowed to vary across individual members. Following the methodology of Pedroni (1999), the co-integrating equation to be estimated for this study from Equation (3.3) is specified as follows:

$$LnREE_{it} = \alpha_i+\delta_t+\alpha_2 LnRGDP_{it}+\alpha_3 LnCE_{it}+\alpha_4 LnOILP_{it}+\mu_{it} \quad (4)$$

Where denotes country and *t* denotes time, α_i represents the country-specific effects, δ_t is the deterministic time trend and μ_{it} is the estimated residual.

From the co-integration testing of Equation (3.4), there are two alternative specification of auxiliary regressions possible, Equation (3.5) and equation (3.6) representing the semi-parametric and the parametric case, respectively.

$$\mu_{it} = \rho\hat{\mu}_{it-1} + \varepsilon_{it} \quad (5)$$

$$\mu_{it} = \rho\hat{\mu}_{it-1} + \sum_{p=1}^{pi} \varnothing_{ip}\Delta\hat{\mu}_{it-p} + \epsilon_{it} \quad (6)$$

The following co-integration test statistics derived based on the estimated residuals are:

Panel v statistics:

$$Z_{\hat{v}NT} = (\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\mu}_{it-1}^{2}) \quad (7)$$

Panel rho statistics:

$$Z_{\hat{\rho}NT} = (\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{\mu}_{it-1}^{2})^{-1}\sum_{i=1}^{N}\sum_{t=1}^{T}(\hat{\mu}_{it-1}\Delta\hat{\mu}_{it} - \hat{\lambda}_i) \quad (8)$$

Panel t statistics (semi-parametric):

$$Z_{tNT} = (\hat{\sigma}_{NT}^{2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{\mu}_{it-1}^{2})^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}(\hat{\mu}_{it-1}\Delta\hat{\mu}_{it} - \hat{\lambda}_i) \quad (9)$$

Panel t statistics (parametric):

$$Z_{tNT}^{*} = (\hat{s}_{NT}^{*2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\mu}_{it-1}^{2})^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11}^{-2}\hat{\mu}_{it-1}\Delta\hat{\mu}_{it} \quad (10)$$

Group rho statistics:

$$\hat{Z}_{\hat{\rho}NT-1} = \sum_{i=1}^{N}\left[(\sum_{t=1}^{T}\hat{\mu}_{it-1}^{2})^{-1}\sum_{t=1}^{T}(\hat{\mu}_{it-1}\Delta\hat{\mu}_{it} - \hat{\lambda}_i)\right] \quad (11)$$

Group t statistics (semi-parametric):

$$\hat{Z}_{tNT-1} = \sum_{i=1}^{N}\left[(\sigma_i^{2}\sum_{t=1}^{T}\hat{\mu}_{it-1}^{2})^{-1/2}\sum_{t=1}^{T}(\hat{\mu}_{it-1}\Delta\hat{\mu}_{it} - \hat{\lambda}_i)\right] \quad (12)$$

Group t statistics (parametric):c

$$\hat{Z}_{tNT}^{*} = \sum_{i=1}^{N}[(\hat{s}_i^{*2}\sum_{t=1}^{T}\hat{\mu}_{it-1}^{2})^{-1/2}\sum_{t=1}^{T}(\hat{\mu}_{it-1}\Delta\hat{\mu}_{it})] \quad (13)$$

Note: The t statistics is referred to as PP here after.

Equation (3.7) to (3.13) are the Pedroni derived seven different test statistics to test for long run relationship. These test statistics can be categorised into two groups: The first group which is regarded as the within-dimension approach comprising of panel statistics, panel rho statistics, panel PP statistics and panel ADF statistics. The other group is called the between-dimension approach and comprises of group rho statistics, group PP statistics and group ADF statistics. According to Mitic et al. (2017), the within dimension group estimators effectively pool the autoregressive coefficient across different members for the unit root test on the estimated residual, whereas the between-dimension group estimators take the average of the individual estimated coefficients for each member.

3.2.3. Granger causality test

Given that two variables are co-integrated, this indicates that there is some sort of causal relationship between the two variables in the long run. The Granger causality test is used to determine the direction of causality between the variables in the model. However, it is important to note that causality does not indicate the direction of relationship.

3.3. Data

The data used for this study is based on annual data from 2001 to 2014 and a sample of forty (40) Sub-Saharan African countries covering the sub-regions: Central Africa, East Africa, Southern Africa and West Africa. The number of countries is informed by data availability over the period of estimation. The macroeconomic variables used in the study are renewable energy consumption, RGDP, carbon emissions and oil prices (Tables 1 and 2).

4. EMPIRICAL FINDINGS AND DISCUSSION

The results of the panel unit root test based on LLC and IPS for the macroeconomic variables are presented in Table 3. The findings provide mixed results, especially in the case of both carbon emissions and oil prices where the LLC test indicates that both macroeconomic variables are stationary at levels, whereas the IPS test reveals that they are stationary after first difference. For renewable energy consumption and RGDP, both LLC and IPS indicate that the variables are stationary after first difference. More importantly, the IPS test indicates that the macroeconomic variables are stationary after first difference and thus integrated of order one.

Having established that an integration order of one for the macroeconomic variables through the IPS test, we adopt the Pedroni (1999) seven tests of panel co-integration. The null hypothesis for all the tests assumes that there is no co-integration. The findings are represented in Table 4 and it indicates that out of the 7 test statistics, 4 test statistics namely Panel PP statistics, Panel ADF statistics, Group PP statistics and Group ADF statistics concludes that there is co-integration, hence a long run relationship between renewable energy and RGDP, carbon emissions as well as oil prices. Our findings are corroborated with that of Arouri et al. (2014) and Fatai (2014) where it was found out that a co-integration exists between renewable energy consumption and economic growth for selected Sub-Saharan African countries. In terms of long run relationship, Nondo and Kahsai (2009) obtained a similar result for COMESA countries, and Bildirici and Kayikci (2016) also obtained similar results while examining the long run relationship existing between energy consumption and economic growth for Eurasian countries. The results, therefore, show that for the selected Sub-Saharan countries there is co-integration, hence a long run convergence between renewable energy and economic growth, carbon emissions as well as oil prices.

For robustness check, we adopt the Kao residual co-integration test. The result is presented in Table 5 and it shows that the ADF test statistics' probability value is significant at the level of 5%. Therefore, we reject the null hypothesis of no co-integration and conclude that the model signifies long run convergence or relationship. This supports the results obtained from the Pedroni co-integration test.

Table 6 shows the findings of the pair-wise Granger causality test. As earlier mentioned, the rule of thumb states that if the probability value is significant at the level of 5%, then we can conclude by rejecting the null hypothesis. With particular emphasis on the causality with renewable energy consumption, the result reveals a bidirectional relationship between renewable energy consumption and RGDP in the selected Sub-Saharan African countries. Also, it can be seen that a unidirectional causal relationship exists between renewable energy and carbon emissions, such that renewable energy consumption granger causes carbon emissions in the selected Sub-Saharan African countries. However, we do not find any causal relationship between renewable energy and oil prices for the selected Sub-Saharan African countries.

Table 1: List of countries

Central Africa	East Africa	Southern Africa	West Africa
Cameroon	Burundi	Angola	Benin
Central Africa Republic	Comoros	Botswana	Burkina Faso
Chad	Djibouti	Namibia	Cape Verde
Congo Democratic Republic	Ethiopia	South Africa	Cote d'Ivoire
Congo Republic	Kenya	Swaziland	Gambia
Equatorial Guinea	Madagascar		Ghana
Gabon	Malawi		Guinea
	Mozambique		Guinea-Bissau
	Rwanda		Liberia
	Mauritius		Mali
	Tanzania		Mauritania
	Uganda		Nigeria
	Zambia		Senegal
			Sierra Leone
			Togo

Table 2: Data description

Data	Identifier	Description	Source	Measurement
Renewable energy consumption	REE	Renewable energy consumption as a percentage of total final energy consumption	WDI (2016)	Percentage
RGDP	RGDP	RGDP measured at 2010 constant prices in US dollars.	WDI (2016)	2010 Constant Basic Prices, Billion (Naira)
Carbon emissions	CE	Total CO_2 emissions from fossil-fuels and cement production	CDIAC	Kiloton (Kt) of Carbon
Crude Oil Price	OILP	Crude oil, average spot price of Brent, Dubai and West Texas Intermediate measured at 2010 US dollars.	World Bank Commodity Price	US Dollar

CDIAC denotes Carbon Dioxide Information Analysis Center and WDI represents World Development Indicators. RGDP: Real gross domestic product

Table 3: Panel unit root test

Variables	Levin, Lim and Chu (LLC)			Im, Pesaran and Shin (IPS)		
	Level	1st difference	Order	Level	1st difference	Order
LnREE	−1.01912 (0.1541)	−17.4316 (0.0000)	I(1)	2.47774 (0.9934)	−12.1954 (0.0000)	I(1)
LnRGDP	−0.15326 (0.4391)	−19.9302 (0.0000)	I(1)	6.87432 (1.0000)	−12.3093 (0.0000)	I(1)
LnCE	−7.49103 (0.0000)	-	I(0)	3.40692 (0.9997)	−13.5505 (0.0000)	I(1)
LnOILP	−7.06337 (0.0000)	-	I(0)	−0.92541 (0.1774)	−14.1567 (0.0000)	I(1)

Source: Researchers' computation from EViews 9.0

Figures in brackets are probability values; Test includes intercept but not a trend

Table 4: Pedroni panel co-integration test

Dimension	Test statistics	Test assumption: Intercept
Within-dimension	Panel v statistic	−0.827574
	Panel rho statistics	2.337897
	Panel PP statistics	−1.817384*
	Panel ADF statistics	−3.506432**
Between-dimension	Group rho statistics	5.027922
	Group PP statistics	−6.057467**
	Group ADF statistics	−6.698667**

Source: Researchers' computation from EViews 9.0

**Significant at 1% level and *significant at 5% level

Table 5: Kao residual panel co-integration test

ADF t-statistics	Probability	Residual variance	HAC variance
−2.506915	0.0061	0.002526	0.002772

Source: Researchers' computation from EViews 9.0

Table 6: Pair-wise granger causality test

Null hypothesis	F-Stat	Probability	Decision	Causality
LRGDP does not granger cause LREE	3.69522	0.0256	Reject	Bidirectional
LREE does not granger cause LRGDP	3.50795	0.0307	Reject	
LCE does not granger cause LREE	1.22031	0.2961	Accept	Unidirectional
LREE does not granger cause LCE	3.27815	0.0386	Reject	
LOILP does not granger cause LREE	0.16109	0.8513	Accept	No causality
LREE does not granger cause LOILP	0.08869	0.9151	Accept	
LCE does not granger cause LRGDP	5.13413	0.0062	Reject	Bidirectional
LRGDP does not granger cause LCE	7.39535	0.0007	Reject	
LOILP does not granger cause LRGDP	2.61452	0.0743	Accept	No causality
LRGDP does not granger cause LOILP	1.83530	0.1607	Accept	
LOILP does not granger cause LCE	4.6429	0.0101	Reject	Unidirectional
LCE does not granger cause LOILP	0.69846	0.4979	Accept	

Source: Researchers' computation from EViews 9.0

5. CONCLUSION

This study investigated whether co-integration exists between renewable energy and economic growth for 40 countries in Sub-Saharan African countries over the period 2001 to 2014. Towards the achievement of this objective, the panel unit root test, panel co-integration test and pair-wise Granger Causality test were employed. The panel unit root test through the use of Levin, Lin and Chu (LLC) test; and Im, Pesaran and Shin (IPS) test provided mixed results. The IPS test showed that all the variables are integrated of the order one. The panel co-integration test was conducted through the Pedroni's seven co-integration test as well as Kao residual co-integration test to obtain efficient results. The panel co-integration test largely provided evidence that there is co-integration amongst renewable energy consumption, economic growth, carbon emissions as well as oil prices for the selected 40 Sub-Saharan African countries.

The pair-wise Granger causality test was conducted to test the growth, conservative, feedback and neutrality hypotheses between renewable energy and economic growth in the selected Sub-Saharan African countries. The findings revealed that a bidirectional relationship exists between renewable energy consumption and economic growth in the selected Sub-Saharan countries. This provides evidence of both the "feedback hypothesis" as observed in the literature implying that renewable energy causes changes in economic growth and also, economic growth causes changes in renewable energy consumption. Also, it was found out that renewable energy granger causes carbon emissions, while there was no evidence of causality between renewable energy and oil prices.

In light of these findings, the study recommends that for the increase of the use of renewable energies in Africa to foster economic growth. This, therefore, calls for the implementation of public policies geared towards the promotion of renewable energies in Africa which could help combat the negative effects of carbon emissions to the environment.

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