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## Article

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

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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; Aroui 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<sub>2</sub>) 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<sub>2</sub> 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, Leita (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, Taghvaei 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<sub>2</sub> 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. Government-

supporting 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<sub>2</sub> emissions and economic growth. Employing yearly data from 1971 to 2013, the authors confirmed the existence of cointegration and causality flows from non-renewable energy consumption to CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> emissions and economic growth. Moreso, the feedback hypothesis was confirmed. CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> emissions mix.

Zaghdoudi (2017) examined the relationship amongst renewable energy, oil prices, CO<sub>2</sub> 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<sub>2</sub> emissions. In addition, following the increased use of renewable energy, the level of CO<sub>2</sub> emissions was reduced. A bidirectional relationship was found between oil prices and CO<sub>2</sub> 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.  $\mu_t$  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 influences 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 states 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:

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

Where denotes country and  $t$  denotes time,  $\alpha_i$  represents the country-specific effects,  $\delta_i$  is the deterministic time trend and  $\mu_{it}$  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.

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

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

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

Panel v statistics:

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

Panel rho statistics:

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

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):

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

Group rho statistics:

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

Group t statistics (semi-parametric):

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

Group t statistics (parametric):c

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

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 <sub>2</sub> 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	1 <sup>st</sup> difference	Order	Level	1 <sup>st</sup> 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.

## REFERENCES

- Abolhosseini, S., Heshmati, A., Altmann, J. (2014), The Effect of Renewable Energy Development on Carbon Emissions Reduction: An Empirical Analysis for the EU-15 Countries. IZA Discussion Paper No. 7989, Forschungsinstitut zur Zukunft der Arbeit/Institute for the Study of Labor.
- Alege, P., Adediran, O., Ogundipe, A. (2015), Pollutant Emissions, Energy Consumption and Economic Growth in Nigeria: A Multivariate Granger Causality Framework. CU-ICADI Ota, Ogun State, Nigeria: International Conference on African Development Issues.
- Alege, P., Osabuohien, E. (2010), G-Localization as a Development Model: Economic Implications for Africa. Annual Conference of Global Economic Analysis Conference, Bangkok.

- Amri, F. (2017), Intercourse across economic growth, trade and renewable energy consumption in developing and developed countries. *Renewable and Sustainable Energy Reviews*, 69, 527-534.
- Apergis, N., Payne, J.E. (2011), On the causal dynamics between renewable and non-renewable energy consumption and economic growth in developed and developing countries. *Energy Systems*, 2(3-4), 299-312.
- Armeanu, D.S., Vintila, G., Gherghina, S.C. (2017), Does renewable energy drive sustainable economic growth? Multivariate panel data evidence for EU-28 countries. *Energies*, 10, 1-21.
- Arouri, M.E., Youssef, A.B., M'Henni, H., Rault, C. (2014), Energy use and economic growth in africa: A panel granger-causality investigation. *Economics Bulletin*, 34(2), 1247-1258.
- Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., Farhani, S. (2018), How economic growth, renewable electricity and natural resources contribute to CO<sub>2</sub> emissions? *Energy Policy*, 113, 356-367.
- Belaid, F., Youssef, M. (2017), Environmental degradation, renewable and non-renewable electricity consumption, and economic growth: Assessing the evidence from Algeria. *Energy Policy*, 102, 277-287.
- Ben Jebli, M., Ben Youssef, S., Ozturk, I. (2015), The role of renewable energy consumption and trade: environmental kuznets curve analysis for sub-saharan Africa countries. *African Development Review*, 27(3), 288-300.
- Bildirici, M., Ozaksoy, F. (2015), Woody Biomass Energy Consumption and Economic Growth in Sub-Saharan Africa. Istanbul, Turkey: Istanbul Conference of Economics and Finance.
- Boden, T., Marland, G., Andres, R. (2012), Global, Regional, and National Fossil-Fuel CO<sub>2</sub> Emissions. Tennessee: Carbon Dioxide Information Analysis Center.
- Boontome, P., Therdyothin, A., Chontanawat, J. (2017), Investigating the Causal Relationship between Non-Renewable and Renewable Energy Consumption, CO<sub>2</sub> Emissions and Economic Growth in Thailand. International Conference on Alternative Energy in Developing Countries and Emerging Economies. Bangkok, Thailand: Energy Procedia. p925-930.
- Bozkurt, C., Akan, Y. (2014). Economic Growth, CO<sub>2</sub> Emissions and Energy Consumption: The Turkish Case. *International Journal of Energy Economics and Policy*, 4(3), 484-494.
- Brini, R., Amara, M., Jemmali, H. (2017), Renewable energy consumption, international trade, oil price and economic growth inter-linkages: The case of Tunisia. *Renewable and Sustainable Energy Reviews*, 76, 620-627.
- Cherni, A., Jouini, S.E. (2017), An ARDL approach to the CO<sub>2</sub> emissions, renewable Energy and economic growth nexus: Tunisian evidence. *International Journal of Hydrogen Energy*, 42(48), 29056-29066.
- Cho, S., Heo, E., Kim, J. (2015), Causal relationship between renewable energy consumption and economic growth: Comparison between developed and less-developed countries. *Geosystem Engineering*, 18(6), 284-291.
- EIA. (2017), International Energy Outlook 2017. Washington: U.S. Energy Information Administration.
- Farhani, S. (2015), Renewable Energy Consumption, Economic Growth and CO<sub>2</sub> Emissions: Evidence from Selected MENA Countries. IPAG Working Paper 612, IPAG Business School.
- Fatai, B.O. (2014), Energy consumption and economic growth nexus: Panel co-integration and causality tests for Sub-Saharan Africa. *Journal of Energy in Southern Africa*, 25(4), 93-100.
- Fotourehchi, Z. (2017), Renewable energy consumption and economic growth: A case study for developing countries. *International Journal of Energy Economics and Policy*, 7(2), 61-64.
- IEA. (2014), Africa Energy Outlook: A Focus on Energy Prospects in Sub-Saharan Africa. World Economic Outlook Special Report, International Energy Agency.
- Im, K., Pesaran, M., Shin, Y. (2003), Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, 115, 53-74.
- IRENA. (2013), Africa's Renewable Future: The Path to Sustainable Growth. Abu Dhabi, United Arab Emirates: International Renewable Energy Agency.
- IRENA. (2016), Renewable Energy Benefits: Measuring the Economics. Abu Dhabi, United Arab Emirates: International Renewable Energy Agency.
- JRC. (2011), Renewable Energies in Africa. European Commission, Joint Research Centre. European Union.
- Kahia, M., Aissa, M.S., Lanouar, C. (2017), Renewable and non-renewable energy Use - Economic growth nexus: The case of MENA net oil importing countries. *Renewable and Sustainable Energy Reviews*, 71, 127-140.
- Kao, C. (1999), Spurious regression and residual-based tests for cointegration in panel data. *Journal of Econometrics*, 90, 1-44.
- Kareem, S.D., Kari, F., Alam, G.M., Adewale, A., Oke, O.K. (2012), Energy consumption, pollutant emissions and economic growth: China experience. *International Journal of Applied Economics and Finance*, 6(9), 136-147.
- Kocak, E., Sarkgunesi, A. (2017), The renewable energy and economic growth nexus in black sea and balkan countries. *Energy Policy*, 100, 51-57.
- Leitao, N.C. (2014), Economic growth, carbon dioxide emissions, renewable energy and globalization. *International Journal of Energy Economics and Policy*, 4(3), 391-399.
- Levin, A., Lin, C., Chu, C. (2002), Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics*, 108, 1-24.
- Lin, B., Moubarak, M. (2014), Renewable energy consumption – economic growth nexus for China. *Renewable and Sustainable Energy Reviews*, 40, 111-117.
- Mitic, P., Ivanovic, O.M., Zdravkovic, A. (2017), A cointegration analysis of real GDP and CO<sub>2</sub> emissions in transitional economies. *Sustainability*, 9, 1-18.
- Nondo, C., Kahsai, M. (2009), Energy Consumption and Economic Growth: Evidence from COMESA Countries. Atlanta, Georgia: Southern Agricultural Economics Association Annual Meeting.
- Ogundipe, A., Olurinola, O., Odebiyi, J. (2015), Examining the validity of EKC in Western Africa: Different pollutants option. *Environmental Management and Sustainable Development*, 4(2), 69-90.
- OXFAM. (2017), The Energy Challenge in Sub-Saharan Africa: A Guide for Advocates and Policy Makers: Generating Energy for Sustainable and Equitable Development. Oxfam America: OXFAM Research Backgrounders.
- Pao, H.T., Fu, H.C. (2013), Renewable energy, non-renewable energy and economic growth in Brazil. *Renewable and Sustainable Energy Reviews*, 25, 381-392.
- Pedroni, P. (1999), Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and Statistics*, 61, 653-670.
- Sebri, M., Salha, O.B. (2013), On the Causal Dynamics between Economic Growth, Renewable Energy Consumption, CO<sub>2</sub> Emissions and Trade Openness: Fresh Evidence from BRICS Countries. Munich Personal RePEc Archive.
- Senturk, C., Sataf, C. (2015), The Determination of Panel Causality Analysis on the Relationship between Economic Growth and Primary Energy Resources Consumption of Turkey and Central Asian Turkish Republics. World Conference on Technology, Innovation and Entrepreneurship. Procedia-Social and Behavioral Sciences. p393-402.
- Silva, S., Soares, I., Pinho, C. (2012), The impact of renewable energy sources on economic growth and CO<sub>2</sub> emissions - A SVAR approach.



- European Research Studies, 15 Special Issue, 133-144.
- Sy, A. (2016), Africa: Financing Adaptation and Mitigation in the World's Most Vulnerable Region. Africa: Brookings Institution, Africa Growth Initiative.
- Taghvaei, V.M., Shirazi, J.K., Boutabba, M.A., Aloo, A.S. (2017), Economic Growth and renewable energy in Iran. *Iran Economic Review*, 21(4), 789-808.
- Thombs, R.P. (2017), The paradoxical relationship between renewable energy and economic growth: A cross-national panel study, 1990-2013. *Journal of World-Systems Research*, 23(2), 540-564.
- Tiwari, A.K. (2011), Energy consumption, CO<sub>2</sub> emissions and economic growth: A revisit of the evidence from India. *Applied Econometrics and International Development*, 11(2), 165-189.
- Troster, V., Shahbaz, M., Uddin, G.S. (2018), Renewable Energy, Oil Prices, and Economic Activity: A Granger-Causality in Quantiles Analysis. Munich Personal RePEc Archive.
- UNFCCC. (2016), Africa is Particularly Vulnerable to the Expected Impacts of Global Warming. UN Climate Change Conference. Nairobi: United Nations Framework Convention on Climate Change. p2.
- United Nations. (2017), World Population Prospects. United Nations: Department of Economic and Social Affairs.
- York, R., McGee, J.A. (2017), Does renewable energy development decouple economic growth from CO<sub>2</sub> emissions? *Socius: Sociological Research for a Dynamic World*, 3, 1-6.
- Zaghdoudi, T. (2017), Oil prices, renewable energy, CO<sub>2</sub> emissions and economic growth in OECD countries. *Economics Bulletin*, 37(3), 1844-1850.