Re-visiting the renewable energy –economic growth nexus. Empirical evidence African OPEC countries

Oluwafisayo Alabi

School of Humanities and Social Sciences
International Public Policy Institute
University of Strathclyde,
Oluwafisayo.alabi@strath.ac.uk,

Ishmael Ackah

Institute for Oil and Gas Studies,
University of Cape Coast
And Department of Economics, Kwame Nkrumah University of Science and Technology, Ghana
ackish85@yahoo.com

Abraham Lartey

Department of Economics,
University of Alicante, Spain
al112@alu.ua.es

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Abstract

This paper investigates the dynamic relationship between renewable energy and economic growth in African OPEC member countries (Angola, Algeria and Nigeria). The fully modified Ordinary Least Squares (FMOLS) technique for heterogeneous cointegrated panels (Pedroni, 2000) is used to estimate the parameters of the model. The study revealed four main findings. First, there is a bidirectional causality between renewable energy and economic growth in the long and the short run. Secondly, a bidirectional causality exists between non-renewable energy and economic growth in the short and long run. Thirdly, a bidirectional causality exists between CO_2 emissions and economic growth. Fourthly, a unidirectional causality was also found between CO_2 emissions and non-renewable energy consumption with the direction of causality stemming from the consumption of non-renewable energy to CO_2 emissions. Since renewable consumption enhances growth, OPEC-member Africa countries should encourage investment in modern renewable sources that has high conversion efficiency such as solar, wind and hydro in order to strengthen their response to mitigating the impacts of climate change.

Key words: Renewable Energy Demand, Economic Growth, Energy, CO2

1. Introduction

The intergovernmental panel on climate change (IPCC) third assessment report (IPCC, 2001) and the United Nations (UN) facts sheet on climate change (UN, 2006) declared African economies as the most vulnerable and at risk to the impacts of climate change. These impacts are estimated to be driven by increasing energy demand, and changing temperatures across African regions, which have potential to ultimately threaten sustainable development (UN, 2006). Since the establishment of the United Nations Framework Convention on Climate Change (UNFCCC) in 1994, there have been various mechanisms, actions and strategies to support developing countries, in particular Africa countries, in mitigating and adapting to climate change. The Kyoto protocol enforced in 2005, set a legal obligation of reduction in emission of developed countries at 5.2% from 1990 levels for the period 2008-2012. Whilst developing countries, faced no restriction on emission, however, were required to adopt policies and mechanisms that promote greener growth (UNFCCC, 1998). In addition to this, the Kyoto protocol also made provision for developing countries to receive financial and technological support from developed countries to counter the impacts of climate change (UNFCC,1998).

Subsequently, in December 2015, after more than 2 decades of negotiations, at the annual Conference of Parties COP21, also known as the 2015 Paris Climate Conference**,** saw a unified international political response to global climate change challenges. The negotiations, aimed at achieving a legally binding and universal agreement on climate change, with the goal of keeping global warming below 2°C. As at 22nd April, 2016 (Earth Day), about 174 countries have signed this agreement, including more than 20 African countries.

The UNFCCC negotiations and agreement of Kyoto and Paris are crucial for Africa as these provides incentives and support to counter the impacts of climate change. However, there are considerable barriers that stand in the way of mitigating climate change in Africa. For instance, African economies (e.g. Angola, Algeria and Nigeria etc.) are heavy dependent on energy revenues (such as oil, natural gas) in supporting economic growth. According to the World Bank, (2015), oil contributes more than 45% of Gross Domestic Product (GDP) and about 70% of export earnings in oil producing and exporting Africa countries. Since mid-2014, oil prices have dropped drastically, declining to less than $55 per barrel (Brent). The falling oil prices, hits African oil exporting countries the largest, given that global oil prices need to be above $100 per barrel to balance economic budgets and sufficiently support economic growth (IEA, 2016). Additionally, Africa suffers from lack of a diversified economic and energy base despite the abundance of renewable energy sources. Currently, more than 70% of Africa's total energy consumption comes from renewable sources, but almost all from traditional uses of biomass, leaving a huge gap to include other modern sources (IEA, 2015). Essentially modern renewable energy sources have not been effectively harnessed to potentially support a clean development mechanism and sustainable energy future across Africa. As a result, Africa economies remain even more vulnerable to impacts of climate change due to their reliance on of fossil fuels and weak integration of renewable energy sources in energy mix. This trend is predicted to worsen as the amount of untapped fossil fuels reserves has the potential to increase CO_2 beyond any scenario currently estimated (Knopf et al., 2010).

Furthermore, there are significant questions that remain unanswered in the context of production and consumption cleaner and sustainable sources of energy/fuel in Africa. One of these is can renewable energy sources sustain economic growth, given increasing energy demand and population size of most African countries. These indications call for a re-evaluation of policy, initiatives and incentive to responding to climate change issues in Africa. In this study, the fully modified Ordinary Least Squares (FMOLS) technique for heterogeneous cointegrated panels (Pedroni, 2000) is used to revisit the relationship between renewable energy, non-renewable, carbon emission and economic growth in OPEC African member countries. The objective of this study is to provide evidence of the nature of the relationship between economic growth, environmental impacts and cleaner and sustainable energy sources to support policy and response to climate change impacts.

The remainder of the paper is structured as follows. In Section 2 we briefly review literature that have examined the relationship between energy consumption, carbon emissions and economic growth. The third section details the data that used and the methods employed to investigation the links between renewable energy, carbon emissions and economic growth. The empirical results are discussed and presented in Section 4. The final section gives a summary and conclusion of the study.

2. Literature

The empirical literature on the relationship between energy consumption, economic growth and carbon emissions is a well-studied area in energy economic literature and can be grouped into three; (i) the nexus of energy consumption and economic growth, (ii) the nexus of economic growth and carbon emissions and (iii) the nexus of energy consumption, carbon emissions and economic growth.

2.1 Economic growth and energy consumption nexus

The relationship between energy consumption and economic growth has a long history, dating back to pioneer study by Kraft and Kraft (1978) who found unidirectional causality between energy consumption and economic growth for United States for (1947-1974). Subsequently, studies examine the nature or direction of causality between energy consumption (non-renewables and or renewables) and economic growth based on of four possible theoretical hypotheses. These are growth hypothesis, conversation hypothesis, feedback hypothesis and neutrality hypothesis (Ozturk, 2010; Payne, 2009). First, growth hypothesis infers a one directional causality running from energy consumption to economic growth. This implies that energy consumption stimulates economic growth, hence, policy should focus on the expansion of the energy mix, to harness a stronger economic contribution from diverse energy sources (Akinlo, 2009; Mahadevan and Asafu-Adjaye, 2007; Odhiambo, 2010; Payne, 2009; Squalli, 2007; Wolde-Rufael, 2005). Second, conversation hypothesis asserts causality running from economic growth to energy consumption. This implies that as the economy grows there will be increase energy consumption, as such policies should aim at increasing energy efficiency (Chang et al., 2009; Mehrara, 2007; Tiwari et al., 2015; Zachariadis, 2007). Thirdly, if causality runs in both directions between energy consumption and economic growth, this suggests a feedback hypothesis. In this case, energy and economic policies should be explored simultaneously due to complementary nature of energy consumption and economic growth (Apergis and Payne, 2010; Ebohon, 1996; Sadorsky, 2009; Solarin and Shahbaz, 2013; Tamba et al., 2012). Lastly, neutrality hypothesis suggests no causality between energy consumption and economic growth. Therefore, policy need to focus on other factors (e.g. human capital and investment in infrastructure etc.) to facilitate energy consumption and economic growth (Bowden and Payne, 2010; Menegaki, 2011; Yildirim and Aslan, 2012). Ozturk (2010) and Payne 2009) provide a comprehensive of studies that examine the relationship between energy consumption and economic.

2.2 Economic growth and environmental impacts nexus

The relationships between economic growth and environmental impacts is another widely studied area in energy economics literature. Studies in this strand,employ the Environmental

Kuznets Curve (EKC) hypothesis to examine the relationship between energy consumption and economic growth. EKC is derived from Kuznets (1955) hypothesis, it postulates that at early stages of economic growth, environmental impacts increase as economic growth increases, up until a threshold is reached, after which environmental impacts begin to decline as economic growth increases. This trend is interpreted as an inverted U-shaped relationship between economic growth and environmental impacts. EKC is widely used a tool for describing the relationship between measured levels of environmental quality indicators such as CO2, SO2 etc. and economic growth (Apergis and Ozturk, 2015). Some examples of studies that found evidence to support EKC hypothesis include (Hettige *et al.* 1992, Cropper and Griffiths 1994, Selden and Song 1994, Grossman and Krueger 1995, Heil and Selden 1999, Martnez-Zarzoso and Bengochea-Morancho 2004, Dinda and Coondoo 2006). However, several authors have found results that reject the hypothesis of higher economic growth leading to decline in environmental impacts such as (Akbostancı et al., 2009; Holtz-Eakin and Selden, 1995; Ozturk and Acaravci, 2010; Shafik, 1994). For a further survey of literature employing EKC hypothesis (see Coondoo and Dinda, 2002; Dinda, 2004; Stern, 2004)

2.3 Energy consumption, environmental impacts and economic growth nexus

More recent attention has focused on investigating the relationship between energy consumption, environmental impacts and economic growth. For example, Ang, (2007) employ VECM technique to examine the causal relationship between energy consumption, emissions and economic growth for France for period 1960-2000.The results provide evidence of causality from economic growth to energy consumption and carbon emission in the long-run, while energy consumption causes economic growth in the short-run. Apergis and Payne, (2009) examines the relationship between energy-CO2-economic growth for six Central American countries from 1971 to 2004 using a panel VECM approach. The study provides evidence of unidirectional causality from energy consumption to economic growth and from energy consumption to carbon emissions. Whilst a bidirectional relationship was found between economic growth an energy consumption. Pao and Tsai (2011) use cointegration and granger causality VECM to estimate the relationship between energy-environment-economic growth for (Brazil, Russia, India and China) BRIC countries. The results suggest a bidirectional relationship between CO2 and economic growth and energy consumption and CO2.

Turning attention to studies that have considered the relationship between energy consumption, environmental impacts and economic growth for emerging and developing Africa countries the evidence/results are limited. Menyah and Wolde-Rufael (2010) apply granger causality test and found unidirectional causality running from $CO2$ to economic growth, energy consumption to economic growth and energy consumption to $CO2$ in South Africa for the period 1965-2006. In an investigation into the relationship between energy consumption and economic growth in MENA countries, Al-mulali (2011) found bidirectional causality relationship between energy consumption, $CO2$ and economic growth using ARDL approach from 1980-2009. Arouri *et al.* (2012), on the other hand, found unidirectional causality running from economic growth to $CO2$ in MENA countries using Bootstrap panel and cointegration approach. Kivyiro and Arminen (2014) analyse the causal relationship between energy consumption, $CO2$ and economic growth in 6 Sub Saharan African countries from 1971 to 2009. Their findings suggest that economic growth granger causes environmental impacts and energy consumption granger causes $CO2$.

Recent studies by Asongu *et al.* (2016) test the relationship between energy,$CO2$ and economic growth for 24 African countries using a panel ARDL approach. The result suggests that in the in the short-run there is no causality between economic growth and energy consumption. However, in the long run relationship causality runs from economic growth to $CO2$ and energy consumption. Esso and Keho (2016) applied cointegration and the granger causality test to examine the long-run and causal relationships between energy consumption, $CO2$ emissions and economic growth of 12 Sub-Sahara African countries. Empirical findings show evidence of unidirectional causality running from economic growth to $CO2$ emissions in Benin, Democratic Republic of Congo, Ghana, Nigeria and Senegal. However, $CO2$ granger causes economic growth for Gabon, Nigeria and Togo.

A comprehensive survey of the three main strands of the relationship between energy consumption environmental impacts and economic growth (see Ozturk 2010, Payne 2010, Omri 2014, Tiba and Omri 2016, Adewuyi and Awodumi 2016). In reviewing the literature, a general observation is that most studies focus on developed countries and very limited literature on emerging and developing countries. However, there is a consensus among previous studies that suggest that these country groups suffer from major energy deficiencies (e.g. energy shortages, poor energy grid/network and poor access to energy etc.) and fluctuating levels of economic growth (Ebohon 1996, Amaewhule 2002, Wolde-Rufael 2005, Akinlo 2008, Ackah *et al.* 2016). Moreover, most of these countries (e.g. Algeria, Angola and Nigeria) are heavy dependent on energy revenues (e.g. oil) to support economic growth, although there are other factors that determine energy consumption across these countries (Ackah and Kizys, 2015). Furthermore, several factors such as population size, poverty, socio-political and terrorism-related upheavals can potentially create instability and distort economic growth in these countries (Carmignani and Kler, 2016).

In this paper, we contribute to the literature by investigating the dynamic relationship between renewable energy and economic growth in oil producing and exporting African OPEC countries (Angola, Algeria and Nigeria). The paper examines if the abundance of non-renewable energy sources such as oil amongst other sources affects direction of causality between energy consumption, carbon emissions and economic growth. At the same time considering if the abundance of renewable energy in these countries has potentially to facilitate economic growth and reduce carbon emissions.

Table 1: Summary of literature on the relationship between energy consumption and economic Growth

Author(s)	Country/countries	Years	Method	Conclusion
Akinlo (2009)	Nigeria	1980-2006	Cointegration and VECM	Growth hypothesis
Al-mulali (2011)	MENA	1980-2009	ARDL	Feedback hypothesis
Ang (2007)	France	1960-2000	VECM	Conversation hypothesis
Apergis and Ozturk (2015)	14 Asian countries	1990-2011	Multivariate framework	Evidence of EKC
Apergis and Payne (2009)	Central America	1971-2004	Panel cointegration technique	Conversation hypothesis
Arouri et al (2012)	12 MENA	1981-2005	Bootstrap panel cointegration	Evidence of EKC
Asongu (2016)	24 African	1971-2011	ARDL	Conservation hypothesis
Bowden and Payne (2010)	US	1949-2006	Toda-Yamanto	Neutrality hypothesis
Chang et.,al (2009)	G7 countries	1997-2006	Threshold estimation	Conservation hypothesis
Ebohon (1996)	Nigeria and Tanzania	1960-1994	Granger causality test	Feedback hypothesis
Esso and Keho (2016)	12 SSA countries	1971-2010	Granger causality test	All four hypothesis
Jumbo (2004)	Malawi	1970-1999	Granger causality test	Evidence of EKC
Kivyiro and Arminen (2014)	6 SSA countries	1971-2011	Granger causality test	Conversation hypothesis
Kraft and Kraft (1978)	US	1947-1974	Toda-Yamamto	Growth hypothesis
Mehrara (2007)	11 oil exporting countries	1971-2002	Toda Yamamoto	Growth hypothesis
Menegaki (2011)	27 European countries	1997-2007	Cointegration and VECM	Growth hypothesis
Menyah and Wolde-Rufael (2010)	South Africa	1965-2006	Granger causality test	Growth hypothesis
Odhiambo (2010)	South Africa	1971-2006	simultaneous-equations	feedback hypothesis
Omri (2014)	14 MENA	1990-2011	Toda-Yamamto	All four hypothesis
Pao and Tsai (2011)	BRIC countries	1971-2011	Bound test approach	Conversation hypothesis
Payne (2009)	US	1946-2006	Panel Cointegration technique	Conversation hypothesis
Sadorsky (2009)	18 emerging countries	1994–2003	Random effect model	Neutrality
Solarin and Shabhaz (2013)	Angola	1971-2009	Ordinary least squares (OLS)	Feedback hypothesis
Squalli (2007)	11 OPEC countries	1980-2003	ARDL,Tado-Yamamto	Conversation hypothesis
Tamba et.al 2012	Cameroon	1975-2008	Bootstrap causality test	Neutrality hypothesis
Tiwari et al (2015)	12 SSA countries	1971-2011	Conintegration	Conversation hypothesis
Wolde-Rufael (2005)	19 African countries	1971-2001	Error correction	Feedback hypothesis
Yidirim and Aslan (2012)	17 OECD countries	1970-2009	Error correction	Feedback hypothesis
Zachariadis (2007)	G7	1960-2004	ARDL	Feedback hypothesis

Table 2. Summary of causal studies in Africa

Author(s)	Country/countries	Period	Method	Conclusion
Akinlo (2009)	Nigeria	1980-2006	Cointegration	Growth hypothesis
Asongu (2016)	24 African	1971-2011	ARDL	Conservation hypothesis
Ebohon (1996)	Nigeria &Tanzania	1960-1994	Granger causality	Feedback hypothesis
Esso and Keho (2016)	12 SSA countries	1971-2010	Granger causality	All four hypothesis
Jumbo (2004)	Malawi	1970-1999	Granger causality	Evidence of EKC
Kivyiro and Arminen (2014)	6 SSA countries	1971-2006	Granger causality	Conversation hypothesis
Menyah and Wolde-Rufael (2010)	South Africa	1965-2006	Granger causality	Growth hypothesis
Odhiambo (2010)	Tanzania	1971-2006	ARDL	Feedback hypothesis
Solarin and Shabhaz (2013)	Angola	1971-2009	OLS	Feedback hypothesis
Tamba et.al 2012	Cameroon	1975-2008	Bootstrap causality	Neutrality hypothesis
Tiwari et al (2015)	12 SSA countries	1971-2011	Conintegration	Conversation hypothesis
Wolde-Rufael (2005)	19 African countries	1971-2001	Error correction	Feedback hypothesis

3 Method

3.1 Data

The study examined the dynamic causality between energy consumption (renewable and non-renewable), CO2 emissions and economic growth in OPEC member African countries (Nigeria, Angola and Algeria). The study employed annual data spanning from 1971 to 2011. Data on renewable energy, non-renewable energy and CO2 emissions were sourced from International Energy Agency (IEA). Data on GDP was collected for each country from the World Bank data bank. Gross domestic product per capita (Y) is expressed in real 2005 US Dollars (USD). Renewable energy consumption (REN) and Non-Renewable energy consumption are measured in kg per capita of oil equivalent. CO2 emissions (C) are expressed in tons per capita.

Most macroeconomic time series according to Asteriou and Hall (2007) are trended and as a result happen to be non-stationary on several occasions. Thus it is very imperative to conduct pre-tests such as unit root and cointegration to circumvent the problem of spurious regression. These specific tests are described in the sections that follows.

3.2 Unit Root Test

In order to ascertain the order of integration of the variables, the panel unit root rest was conducted using three main tests. These are the Levin, Lin and Chu (LLC), Im, Pesaran and Shin (IPS) and Phillips and Perron (PP) tests. Among these tests, LLC is based on the assumption of a common unit root process that the autocorrelation coefficients of the tested variables across cross sections are identical. However, the IPS and PP rely on the individual unit root process assumption that the autocorrelation coefficients vary across cross sections. In the LLC, IPS and PP tests, cross-sectional means are subtracted in order to minimize problems arising from cross-sectional dependence. The Akaike information criterion (AIC) was used to determine the country-specific lag length for the ADF regressions, with a maximum lag of 3 regarding the LLC and the IPS tests. Further, the Bartlett kernel was used to estimate the long run variance in the LLC test, with the maximum lags determined by the Newey-West bandwidth selection algorithm.

3.3 Panel Test for cointegration.

The study makes use of Kao test for cointegration to test for the existence of long run relationship among the variables since it was established that the variables are integrated of order one. Kao (1999) describes two tests under the null hypothesis of no cointegration for panel data. One is a Dickey-Fuller type test and another is an Augmented Dickey-Fuller type test

$y_{it} = \alpha_i + \beta x_{it} + e_{it}$ i =1,….N, t=1,….T……………………………………………**(1)**

Where

$y_{it} = y_{it-1} + \mu_{it}$

$x_{it} = x_{it-1} + \varepsilon_{it}$

α_i are the fixed effect varying across the cross-section observations, β is the slope parameter, y_{it} and x_{it} are independent random walks for all i. The residual series e_{it} should be I(1) series. The Dickey-Fuller test can be applied to the estimated residual using

$\hat{e}_{it} = \rho \hat{e}_{it-1} + \upsilon_{it}$

The null and alternative hypothesis is therefore written as $H_0 : \rho = 1$

$H_0 : \rho < 1$

3.4 Long run model

The long run relationship between CO2 emissions, renewable and non-renewable energy consumption and economic growth is specified as

$$\ln C_{it} = \beta_0 + \beta_1 \ln NRENC_{it} + \beta_2 \ln RENC_{it} + \beta_3 \ln \ln Y_{it} + \mu_{it} \quad \text{……………………………….}\mathbf{(2)}$$

The fully modified OLS (FMOLS) technique for heterogeneous cointegrated panels is estimated (Pedroni, 2000) is used to estimate the parameters of the model. FMOLS can be used to estimate the asymptotically efficient consistent in panel series where the method takes in to consideration non-exogeneity, serial correlation and heterogeneity (Pedroni, 1996).The parameters estimated represents the long run elasticities since the model is specified in log form.

3.5 Granger Causality test

The dynamic causality between renewable energy consumption, non-renewable energy consumption, CO2 and economic growth were estimated using panel vector error correction model based on the two step Engle and Granger (1987) procedure. This was done by first estimating the long run relationship and saving the residuals. The lagged residuals then serve as the error correction term for the vector error correction model as follows;

$$\Delta Y_{it} = \psi_{1i} + \sum_{k=1}^{n} \psi_{11ik} \Delta Y_{it-k} + \sum_{k=1}^{n} \psi_{12ik} \Delta NREC_{it-k} + \sum_{k=1}^{n} \psi_{13ik} \Delta REC_{it-k} + \sum_{k=1}^{n} \psi_{14ik} \Delta C_{it-k} + \eta_{1it} ECT_{it-1} + \mu_{1it} \quad \text{…..}\mathbf{(3)}$$

$$\Delta NREC_{it} = \psi_{2i} + \sum_{k=1}^{n} \psi_{21ik} \Delta NREC_{it-k} + \sum_{k=1}^{n} \psi_{22ik} \Delta Y_{it-k} + \sum_{k=1}^{n} \psi_{23ik} \Delta REC_{it-k} + \sum_{k=1}^{n} \psi_{24ik} \Delta C_{it-k} + \eta_{2it} ECT_{it-1} + \mu_{2it} \quad \text{…..}\mathbf{(4)}$$

$$\Delta REC_{it} = \psi_{3i} + \sum_{k=1}^{n} \psi_{31ik} \Delta REC_{it-k} + \sum_{k=1}^{n} \psi_{32ik} \Delta Y_{it-k} + \sum_{k=1}^{n} \psi_{33ik} \Delta NREC_{it-k} + \sum_{k=1}^{n} \psi_{34ik} \Delta C_{it-k} + \eta_{3it} ECT_{it-1} + \mu_{3it} \quad \text{…..}\mathbf{(5)}$$

$$\Delta C_{it} = \psi_{4i} + \sum_{k=1}^{n} \psi_{41ik} \Delta C_{it-k} + \sum_{k=1}^{n} \psi_{42ik} \Delta Y_{it-k} + \sum_{k=1}^{n} \psi_{43ik} \Delta NREC_{it-k} + \sum_{k=1}^{n} \psi_{44ik} \Delta REC_{it-k} + \eta_{4it} ECT_{it-1} + \mu_{4it} \quad \text{….}\mathbf{(6)}$$

Where Δ is the first-difference operator; k (k=1,…,n) is the optimal lag length selected based on Schwarz Information Criterion (SIC), μ the serially uncorrelated error term and

ECT_{it-1} is the estimated lagged error correction term derived from the long-run cointegrating relationship. The causality in the short run is determined by the statistical significance of the partial F-statistics connected with the right hand variables On the other hand the causal relation in the long run is revealed by the statistical significance of the t -statistic of the respective error correction terms.

4. Results and Discussions

Table 3 summarizes descriptive statistics of the variables used in our study. All variables are expressed in real per capita terms. Gross domestic product per capita (Y) is expressed in real 2005 US Dollars (USD). Renewable energy consumption (REN) and Non-Renewable energy consumption are measured in kg per capita of oil equivalent. CO2 emissions (C) are expressed in tons per capita. Over the sample period and across countries, the mean of real GDP is 1,465 real USD per capita. Real GDP per capita varies between 153 and 5482.432USD per capita. The degree of variability is also witnessed by the standard deviation. Real GDP deviates from its mean on average by 1333.625 USD per capita. The data for this variable are positively skewed (with the value of the skewness standing at 1.361) and leptokurtic (with the value of kurtosis of 4.1581). The latter suggests that the distribution of real GDP across countries and over time features heavy tails, whereas the former suggests that positive deviations from the mean tend to be more dispersed than negative deviations.

Overall, positive skewness and kurtosis collectively result in a non-normal distribution, as indicated by the Jarque–Bera test statistic and the associated probability value. CO2 emissions per capita are on average are estimated at 0.260 t per capita across countries and over time. The data vary between 0.022 and 1.103 t per capita. The range of variation causes the data to deviate from the sample mean by 0.317 t per capita. Again, we observe positive skewness (with the asymmetry coefficient standing at 1.365) and kurtosis (with the value of kurtosis standing at 3.417). Subsequently, the Jarque–Bera test statistic provides strong evidence of non-normality in the data. The consumption of non-renewable energy averages 0.219 kg of oil equivalent per capita. The values range between 0.031 and 0.794 kg of oil equivalent per capita with a standard deviation estimated at 0. 185 kg of oil equivalent per capita. It is positively skewed (1.330) and leptokurtic (3.640). Therefore, the Jarque–Bera test statistic unambiguously rejects the null of normality in the data. Lastly, the consumption of renewable energy on the other hand averages 0.286 kg of oil equivalent per capita. The values range from 0.0003 and 0.588 kg per capita, with the standard deviation estimated at 0.222 kg per capita. It is positively skewed (0.21) and leptokurtic (1.495). The Jarque–Bera test statistic, therefore, unambiguously rejects the null of normality in the data.

Table 3: Summary Statistics of Variables

Variables	Obs	Mean	Median	Max	Min	SD	Skew	Kurt	JB	Prob
Y	112	1464.8	923.90	5482.43	153.076	1333.63	1.361	4.1581	40.841	0.000
C	123	0.260	0.089	1.103	0.022	0.317	1.365	3.417	39.089	0.000
NREN	126	0.219	0.118	0.794	0.031	0.185	1.330	3.640	39.337	0.000
REN	126	0.286	0.305	0.588	0.0003	0.222	0.211	1.495	2.832	0.0016

The Pearson coefficients of unconditional correlation among the variables under investigation are reported in Table 4. The results show that non -renewable energy consumption is highly negatively correlated (-0.8095) with the consumption of renewable energy. CO2 emissions per capita is also negatively correlated (-0.7622) with renewable energy consumption per capita. GDP per capita was found to be positively correlated (0.5416) with per capita renewable energy consumption. Non-renewable energy consumption per capita was also found to be correlated positively with CO2 emissions per capita (0.9793) and GDP per capita (0.7288). GDP per capita also revealed a high positive correlation with capital per capita (0.6405).

Table 4: Pearson Correlation Matrix

Variables	REN	NREN	C	Y
REN	1			
NREN	-0.8095	1		
C	-0.7622	0.9793	1	
Y	0.5416	0.7288	0.6405	1

Each unit root test is summarized in two columns. The first column assumes the presence of a constant in the test equation, whereas the second column assumes the presence of both a constant and a linear trend in the test equation. The null hypothesis assumes the presence of a unit root in the variable. If the null is rejected then the variable is deemed to be stationary. In general, the results of the three (3) unit root tests shows that all the variables under consideration are not stationary and hence possess unit roots. The LLC and IPS tests show that all the variables are not stationary. The PP test with no trend indicates that renewable energy consumption per capita is stationary at the 10% level All the other variables are not stationary according to the PP test. The results therefore show that the variables contain unit roots. The study further first differenced the variables and applied the three unit roots again. The results are reported in the second panel of Table 5. It can be seen that all the three tests provide an overwhelming evidence of stationarity when the variables are first difference. It is therefore concluded that all the variables are integrated or order one i.e. I (1)

Table 5: Results of the Panel Unit Root tests

	LLC		IPS		PP	
Variables	Cons	Trend	Cons	Trend	Cons	Trend
	LEVEL					
REN	-0.1941	0.8004	1.6896	3.2029	12.0675*	0.7871
NREN	1.1403	0.1953	2.2855	1.1728	3.6969	1.9502
C	0.7734	0.1161	2.7090	1.4295	1.8246	3.8623
Y	-0.2305	-1.5310	-0.2947	-1.0216	4.4418	2.6929
FIRST DIFFERENCE						
REN	-2.6514***	-4.2216***	-3.061***	-5.0284***	-3.9183***	-5.1287***
NREN	-9.7251***	-8.7085***	-9.697***	-9.8528***	-9.517 ***	-9.2287***
C	-10.285***	-9.0364***	-10.740***	-10.955***	-11.176***	-10.966***
Y	-3.9751***	-3.1331***	-3.8858***	-3.1372***	-8.5793***	-8.0301***

*, *** shows rejection of the null hypothesis at the 10%,and 1% significance level respectively

In order to avoid the problem of spurious regression, we tested if the variables are cointegrated, that is, to ascertain if the variables share a common stochastic trend. To this end, we used the Kao test for cointegration. The null hypothesis of no cointegration is rejected. We thus conclude that the variables share a common stochastic trend.

Table 6: Results of Test for Cointegration

Method	**Test**	**Statistic**	**Prob**
Kao(1999)	ADF	-4.013812	0.0000

We estimated the long run relationship in log levels using the Panel Fully Modified OLS (FMOLS). Since the equation were estimated in log levels, the coefficient represents the long run elasticities. A 1% increase in non- renewable energy consumption per capita decreases CO2 emissions per capita by 1.20% whiles a 1% increase in per capita renewable energy increases CO2 emissions per capita by 0.24%. The result also indicates that a 1% increase in

GDP per capita increases CO2 emissions per capita by 0.83%. The result implies that non-renewable energy consumption in these countries contribute more to CO2 emissions than GDP per capita in the long run.

Table 7: FMOLS estimates of the Long Run Relationship

Variables	Coefficient	STD ERROR	T stat
NRENC	1.204***	0.109	10.956
RENC	-0.239***	0.0219	10.906
Y	0.833***	0.0922	11.960

**** means significant at the 1% significance level .

Next we estimated the dynamic causality between renewable energy consumption, non-renewable energy consumption, CO2 and economic growth in a panel vector error correction model based on the two step Engle and Granger (1987) procedure. A maximum lag length was selected based on Schwarz Information Criterion (SIC). The study revealed a bidirectional causality between renewable energy and economic growth in the long and short run, a bidirectional causality between non-renewable energy and economic growth in the short and long run as well as a bidirectional causality between CO_2 emissions and economic growth. This result is consistent with the findings of Apergis and Payne (2010).

A unidirectional causality was also found between CO_2 emissions and non-renewable energy consumption with the direction of causality stemming from the consumption of non-renewable energy to carbon dioxide emissions.

Table 8: Results of the Panel Causality Test.

Dependent Variable	Direction of causality				
	Short run				Long Run
	ΔY	ΔREN	ΔNREN	ΔC	ECM_{t-1}
ΔY	-	22.09***	180.05***	97.70***	-5.69***
ΔREN	60.04***	-	14.5		-3.26***
ΔNREN	160.27***	2.97	-	4.10	-8.99***
ΔC	97.71***	2.25	35.6***	-	-11.48***

*** means significant at the 1% significance level.

5. Conclusion

This paper investigates the dynamic relationship between renewable energy and economic growth in OPEC member oil producing African countries. The fully modified OLS (FMOLS) technique for heterogeneous cointegrated panels is estimated (Pedroni, 2000) and used to estimate the parameters of the model. The study revealed a bidirectional causality between renewable energy and economic growth in the long and short run. There is also evidence of bidirectional causality between non-renewable energy and economic growth in the short and long run. A bidirectional causality was also found between CO_2 emissions and economic growth. Additionally, there is a unidirectional causality between CO_2 emissions and non-renewable energy consumption with the direction of causality stemming from the consumption of non-renewable energy to carbon dioxide emissions.

These results are consistent with the fact, that for many years, the economic structure of the African OPEC countries studied, has first and foremost, focused on the petroleum industry, as this is their primary source of economic growth and energy/fuel. Their heavy reliance on oil revenues has prevented these economies from devoting both capital and substantial investment to the development of less carbon intensive energy sources. Hence, many of the OPEC economies have failed to effectively mitigate the current impacts of climate change and make have weak response to future climate change impacts. Therefore, we recommend that the energy mix in this countries should integrate more renewable energy sources such as solar, wind and hydro, since it has the potential to stimulate economic growth. Moreover, because of bidirectional relationship between non-renewable energy consumption and economic growth, policy should target higher investments in renewable energy sources to minimise the consumption of non-renewable energy and to support reduction in carbon emissions. Again, in order to curb carbon emissions, effort should also be directed an energy efficiency education and effective demand side management to reduce non-renewable energy consumption.

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