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Renewable Energy Consumption and Economic Growth Nexus in the Central African Sub-Region: Application of Panel Cointegration Approach

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Abstract
The study examined the causal relationship between renewable energy consumption and economic growth patterns in six countries in the Central African Sub-region using a panel data collected for a period of 1990-2015. The Central African Sub-region constitutes the part of Africa where there is abundance of renewable energy resources. The study employed the panel fixed and Random effect models, the Dynamic Ordinary Least squares (DOLS), Fully Modified Ordinary Least squares (FMOLS) and Pairwise Dumitrescu-Hurlin Panel Causality techniques to examine the short and long run impacts of renewable energy on Economic growth. The study found that, economic growth and renewable natural resources have both short run and long run relationships. Again, unidirectional causality was found between renewable energy consumption and economic growth and an inverse relationship was also identified. The study recommends that, government policies should be directed to utilize cost effective renewable technologies to expanding the abundance renewable energy resources to boost productivity, support agriculture and rural industries. This would spur the potentials to propel sustainable economic growth, future energy security while the environment is also protected.
Keywords: Renewable Energy, Economic growth, Central Africa

1. Introduction

In recent times, the growing evidence of climate change effect has stimulated the interest for consumption of renewable energy resources especially in this 21st century where there is persistent unstable oil prices, fast global population growth, industrialization growth, and increased CO2 emission(Menyah & Wolde-Rufael, 2010; Panwar, Kaushik, & Kothari, 2011; Tugcu, Ozturk, & Aslan, 2012).

Renewable energy resources are considered as clean energy which has the potential to minimize the negative impact of greenhouse gasses, while achieving present and future energy security and sustainable development (Panwar et al., 2011). Renewable energy constitutes the energy resources obtained from emerging technologies such as marine energy (wave energy, tidal energy, tidal/ocean currents, salinity gradient, and ocean thermal energy conversion), concentrated solar photovoltaic (parabolic troughs, linear Fresnel reflectors, parabolic dishes, and solar towers), enhanced geothermal energy (EGE), cellulosic ethanol, and artificial photosynthesis (Hussain, Arif, & Aslam, 2017).

Several studies agree that, renewable energy resources' consumption is one of the key factors that can contribute to mitigating CO2 emission, sustainable economic development and future energy security (Apergis & Payne, 2010; Bowden & Payne, 2010; Khobai & Le Roux, 2018; Lin & Moubarak, 2014; Sebri & Ben-Salha, 2014; Sinha, 2014; Vlahinić-Dizdarević & Žiković, 2010). According to (Alper & Oguz, 2016)who examined the causal relationship between economic growth and renewable energy consumption, labour and capital for new EU member countries, renewable energy consumption has positive impact on economic growth. Even though a kind of neutral relationships between renewable energy consumption and economic growth exist among some of the countries. This neutrality nexus according to (Menegaki, 2011) can be attributed to the insufficient exploitation of the renewable energy resources among the member countries investigated.

Nonetheless, several of these studies support that hypothesis that, renewable energy consumption contribute a significant proportion to economic growth. Following this, findings by (Šimelytė & Dudzevičiūtė, 2017) also highlighted the significant relationship between renewable energy in production and economic development. The author also investigated the relationship between renewable energy consumption, trade, capital and labour 28 European Union Countries by employing and concludes that, out of the 28 EU countries investigated, it was evident in 12 countries that renewable energy consumption boots economic growth. Similarly, (Apergis & Payne, 2010; Inglesi-Lotz, 2013) focused on estimating the contribution of renewable energy consumption to the economic growth and development using a panel data from thirty four countries-members of OECD. The results revealed the existence of positive relationship between the share of total energy mix to economic growth and development and particularly the welfare of the people. This implicate that need to promote policies that will ensure efficient consumption of renewable energy resources recognizing the benefits both environmentally and economically.

In china, the role of renewable energy consumption and economic welfare was investigated by (Fang, 2011) who found that, 1% increment in the renewable energy consumption contribute to Real GDP by 0.12%, per capita annual income of rural households by 0.444% and GDP per Capita by 0.162%. In the case of its contribution to the urban Chinese households, the study found that, a 1% increase in the renewable energy consumption increases it by 0.368%. In this study, the author concluded that, renewable energy consumption has insignificant share on the economic welfare of the people and recommended efficient policy refinement to improve the effect of the renewable energy consumption on the economic welfare of the people.

In South Africa, a significant short term and long term relationships between renewable energy consumption and economic growth has been established (Khobai & Le Roux, 2018). The findings further concluded on the direction of the causality flowing between renewable energy consumption and economic growth both in the long run and short run associations. The findings maintain that, in the short run, there was existence of a unidirectional causality flows from economic growth to renewable energy consumption while in the long run, the causality flows from renewable energy consumption to economic growth. This stresses on the impact of the renewable energy consumption on sustainable future economic growth in the future. Corroborated by these findings, (Bhattacharya, Paramati, Ozturk, & Bhattacharya, 2016)investigated the interrelationship between renewable energy consumption and economic growth among the world's major 38 renewable energy consuming countries using energy attractiveness index. The results showed that, there was a cross sectional dependence and heterogeneity across the countries. A long run dynamics of was established between renewable energy consumption and economic growth. Among 57% of the 38 countries, the results proved appositive relationship between renewable energy consumption and economic growth.

In Ghana, (Enu & Havi, 2014) confirmed that , renewable energy generated from electricity contribute to economic growth and estimated that, 100% increase in the electricity output, contribute about 52% of real gross domestic product per capita. The study concluded that, there exist long and short run relationship between electricity consumption and economic growth.

Conflicting to the previous studies, some studies could not identify any causal relationship between renewable energy consumption and economic growth. For example, (Yildirim, Saraç, & Aslan, 2012)found no causal relationship between renewable energy such as hydroelectric power consumption and economic growth. However, one causal relationship was identified between biomass derived energy consumption and GDP. Likewise, (Menegaki, 2011; Payne, 2009) in their studies did not find any causal relationship between renewable energy consumption and economic growth.

Surprising, pioneering studies such as(Karekezi, 2002; Neitzel, 2017; Squalli, 2007; Wolde-Rufael, 2005) have also found that, economic growth have negative impact on renewable energy consumption and this occurs in usually developing economies where several factors such as wide spread of poverty, infrastructural constraints and mismanagement of the energy resources are high. For example, (Squalli, 2007) found that, causality may negatively flow from economic growth to energy consumption particularly in a growing economies countries. In this case, an increased in economic growth may reduce energy consumption especially the renewable energy and this could be as a results of multidimensional factors. Even though It is also possible that production and economic activities are directed towards sectors where renewable energy is utilized and has small impact on economic growth and the vice versa.

Conclusions drawn from these previous studies provide a strong evidence that renewable energy consumption have significant positive impact of economic growth and development(Alper & Oguz, 2016; Bhattacharya et al., 2016; Bowden & Payne, 2010; Enu & Havi, 2014; Lin & Moubarak, 2014; Panwar et al., 2011; Sebri & Ben-Salha, 2014; Tugcu et al., 2012; Vaona, 2012) and limited number of these studies though report a negative effect of growth on renewable energy consumption. However, these studies have mostly been limited to the developed world while the state of renewable energy consumption in the most underdeveloped countries such as the Central African Sub Regions where there is abundance of renewable energy resources is least researched (Fan, Wang, Wei, & Zhang, 2018). Meanwhile studies such as (Karekezi, 2002) confirm that, in Africa, renewable energy resources are abundant even though only small number of the populations have access to these renewable energy resources due to particularly high cost of installation and widespread of poverty among the people. Again, the Karekezi asserts that, several of renewable energy resource technologies such as large-scale biomass energy, small-scale biomass energy, solar photovoltaic, solar thermal; and wind are abundant in the regions. In spite of this, the current state of literature on the relationship between renewable energy consumption and economic growth continue to reveal mixed conclusions, and absence of consensus particularly on the nexus and causality between economic growth and renewable energy consumption between developed and developing countries. This fosters more confusion and leaves the sense of causality between economic growth and renewable energy consumption blur. As most of these studies have been focused in the developed countries, this current study focuses on the situation in the underdeveloped economies such as the Central African Sub-regions where poverty is wide spread and severe infrastructural constrains persist.

Under this background, this current paper investigate to impact and causal nexus between renewable energy consumption, and economic growth and the causality of the relationship by utilizing a panel data from the central African Sub-Regions. The study also introduces new variables; 'electricity output from renewable sources' which has been neglected in many renewable energy studies (Alper & Oguz, 2016; Amri, 2017; Enu & Havi, 2014; Fang, 2011; Menegaki, 2011; Shahbaz, Loganathan, Zeshan, & Zaman, 2015)yet it plays a key role in propelling economic growth and development in developing countries in particular(Enu & Havi, 2014) . This study is among the pioneering studies in this direction to investigate the causal relationship between renewable energy consumption and economic growth in the Central African Sub Regions. The study has a policy implications for sustainable economic growth, quality economic welfare of the people, sustainable future energy supply and agricultural production.

This present study is among the pioneering studies in the Region where a novel multiple comparative estimation procedures such as (Panel fixed and random effects Panel Cointegration estimates using Dynamic Ordinary Least squares (DOLS), panel Fully Modified Ordinary Least squares (FMOLS) and pairwise Dumitrescu Hurling Causality) are employed to double check the robustness of the short and long run dynamics of interplay between renewable energy consumption and economic among the selected countries in the central part of Africa.

2. Data and Methods of Analysis

The study investigated the relationship between renewable energy consumption, electricity output from renewable sources and economic growth in a novel computation environment using a panel data. The study employed the fixed and random effect models as well as panel cointegration and causality models to investigate the short run and long run relationships between renewable energy consumption and economic growth.

The dataset used for the study constituted an annual panel data for six countries in the Central African Sub-region were organized from World Bank Development Indicators (2016) database covering the period of 1990-2015. The countries included Cameroon, Gabon, Equatorial Guinea, Congo, Chad and Democratic Republic of Congo. These countries were chosen out of the nine countries in the central African Sub regions based on data availability. The yearly Gross domestic Product at constant 2010 US dollars(GDP), Renewable energy consumption (RE) as percentage of total final energy consumption, and Renewable electricity output(RELECT) as percentage of total electricity output. Among the variables on GDP variable was transformed to logarithm while the rest of the variables were maintained since they were already in percentages. The panel data properties such as Panel unit root was checked before proceeding with the further analysis.

2.1 Panel unit root test

The study employed three main types of panel unit root tests for robustness and these included Levin, Lin and Chu panel unit root test , proposed by(Levin, Lin, & Chu, 2002), Breitung proposed by (Breitung, 2001), Im, Pesaran and Shin W-stat proposed by(Im, Pesaran, & Shin, 2003) . The panel unit root tests examined the stationary process of each series and the order one process of integration of each of the variables.

The unit root test by(Levin et al., 2002) is based on augmented Dickey-Fuller (ADF) test. The null hypothesis is (H_0: there is a unit root). It assumes cross sectional independence which implies a homogeneity in the dynamics of the autoregressive coefficients. Im et al. (2003) proposed a test based on the mean group approach considering the average of the Z statistic. Levin, Lin and Chu panel unit root test , proposed by(Levin et al., 2002) considers a basic ADF specification given as

$$\Delta y_{it} = \alpha y_{it-1} + \sum_{j=i}^{pi} \beta_{ij} \Delta y_{it-j} + X_{it}' \delta + \epsilon_{it} \qquad (1)$$

Where Δ is the first difference operator, y_{it} is the dependent variable ϵ_{it} is the white noise disturbances and t is the time while i, is the number of countries.

It assumes a common $\alpha = \rho - 1$ where a lag order for the difference terms ρi is however allowed to vary across sections. The null hypothesis H_1: $\alpha = 1$ which implies that there is a unit root while the alternative hypothesis H_1 implies $\alpha < 0$ (there is no unit root)

Im, Pesaran and Shin W-stat proposed by(Im et al., 2003) allows for individual unit root test so that, ρi may vary across differenet cross sections. With this panel unit root test, a separate ADF regression is specified for each cross section from the equation (1) above. In this model, the null hypothesis is written as: H_0: $\alpha_i = 0$ for all i while the alternative hypothesis is also given as

: $H_1: \begin{cases} \alpha_i < 0 \ for\ i = 1,2, \dots N \\ \alpha_i < 0\ for\ i = N+1, N+2 \dots . N \end{cases}$. Hence the i may be ordered which is interpreted as a non-zero fraction of the individual process of stationary. The variables used in the equation (1) included LNGDP, RE and RELECT. After the unit root test, these variable are supposed to have unit root at level but only become stationary at first difference so that the long run relationship can be established. So when they are not stationary at level but at first difference, it implies the variables LNGDP, RE, and RELECT are cointegrated of order one series, thus I(0). This makes it possible to further conduct the cointegration test.

2.2 Panel cointegration tests
The panel cointegration establishes the long rung association between the variable used in the study. The panel cointegration test proposed by (Pedroni, 1999) has largely been used for several studies to check the long run equilibrium among cointegration variables. The test permit the analysis involving two or more independent variables. The panel cointegration allows for cross sectional dependence including both different individual effects, heterogeneous intercepts and deterministic trend. According to the test, the panel cointegration test is performed within two main domains (panel tests statistics within dimension approach and group mean panel tests between dimensions). Pedroni's test yield about seven different statistics based on the null hypothesis of no cointegration. The estimating cointegration model is given as:
$lnGDP_{it} = \alpha_{it} + \delta_{it} + \beta_{1i}\mathrm{RE}_{it} + \beta_{2i}\mathrm{RELECT}_{it} + \epsilon_{it}$ (2)
Where $\epsilon_{it} = \rho_{it}\epsilon_{it-1} + \mu_{it}$ (3)
From the equation (2) above, t reprenst time period, β denotes the slope of the coefficient α_{it} takes care of the country specific effects, δ_{it} represent deterministic effects and ϵ_{it} was included in the model to represent the estimate residual deviations from the long run dynamics.
On the other hand, (Kao, 1999) test uses the ADF type test of residuals with null hypothesis of no cointegration. The Kao test is similar to Pedroni tests, however, it recognizes cross-section specific intercepts as well as cross-section homogeneous regression parameters and this is specified as:
$y_{it} = \alpha_i + \beta X_{it} + e_{it}$ (4)
$y_{it} = y_{it-1} + u_{it}$ (5)
$X_{it} = X_{it-1} + \varepsilon_{it}$ (6)
$\hat{e}_{it} = \rho\hat{e}_{it} + \sum_{j=1}^{\rho}\gamma_i\,\Delta\hat{e}_{it-j} + v_{it-j}$ (7)
Where $\rho$the number of lags is, $\hat{e}_{it}$ is the estimated residual. In this case, null hypothesis of no cointegration is given as $\rho = 1$, the alternative hypothesis of cointegration is
$\rho < 1$. An alternative test is the Johansen Fisher combined test which uses both approaches to estimate the cointegration vectors. The Johansen Fisher combined Panel Cointegration test uses the Trace Statistic tests for at most the number of cointegration vectors and the Maximal Eigenvalue Statistic tests for the exact number of cointegration. The study utilized the Johansen Fisher Panel Cointegration test and Kao residual test of cointegration.

2.3 Panel cointegration estimation (FMOLS and DOLS)
To estimate the long run relationship between the variables, the study employed, two cointegration estimates approaches namely Panel Dynamic Ordinary Least squares (DOLS), and panel Fully Modified Ordinary Least squares (FMOLS). The model is given as:
$lnGDP_{it} = \alpha_i + \delta_{it} + \beta_{1i}\mathrm{RE}'_{it} + \beta_{2i}\mathrm{RELECT}'_{it} + \epsilon_{it}$ (8)
Here the natural log of Gross Domestic Product was used as the depended variable while the rest of the variables were used as explanatory variables in checking the long run effects and estimating their coefficients. This approach has an impressive advantage such that endogeneity bias and serial correlations are corrected by FMOLS and DOLS techniques and also accommodate cross sectional heterogeneity and therefore the estimators are standardized(Pedroni, 2001).

2.4 Panel Causality Test
From the cointegration test above, if the results conclude that, there is long run association between the variables, therefore it becomes necessary to check the direct of causation among the variables. The study utilized the Dumitrescu Hurlin causality technique to examine the causations among GDP, RE, and RELECT. This simple granger causality approach uses the pairwise causation direction considering to variables X and Y at a time. This is written as:
$Y_t = \alpha_1 + \sum_{i=1}^{n}\beta_{1i}X_{t-i} + \sum_{i=1}^{n}\beta_{2i}Y_{t-i} + \varepsilon_{1t}$ (9)
$X_t = \alpha_1 + \sum_{i=1}^{n}\beta_{3i}X_{t-i} + \sum_{i=1}^{n}\beta_{4i}Y_{t-i} + \varepsilon_{2t}$ (10)
Here, the n represents the selected number of lags, $\alpha's$, $\beta's$ are the parameter estimates, X and Y are the variables under investigation while ε_{1t} and ε_{2t} are the error terms.
Moreover, a further modified approach has been developed to analysis such causation particularly with panel data context. If two stationary variables M, N are observed over a period of time t on N individuals, a technique developed by(Dumitrescu & Hurlin, 2012) can be used to estimation the direction of the causation between the variables. The model is constructed as:
$M_{i,t} = v_t + \sum_{c=1}^{c}\mu^{(c)}M_{i,t-c} + \sum_{c=1}^{c}\beta^{(c)}N_{i,t-c} + u_{1,t}$ (11)
From the equation, the u is the error term and t is the time period.

2.5 Fixed and Random Effect Models

The study further estimates the two types of panel data models namely: fixed and random effects models to broaden the discussions on the analysis on the relationship between economic growth and renewable energy consumption and export

The fixed effect model is appropriately used when there is a correlation between the individual effects of the various countries selected and Determinants of growth. The model assumes heterogeneity or differences across the observed units and helps to eliminate the time specific invariant effect. On the other hand, if there exist no correlation between the individual effects of the selected countries and their determinants of growth, then the random effect model is suitable.

However, due to the nature of the countries selected from the same sub-region which although may have common history, resources, colonization but different growth rates, and other economic fundamentals, the use of the two models would be more appropriate. The fixed effect model is one of the panel models with constant slopes with varying intercepts. The model is specified as:

$$Y_{it} = \alpha_i + \beta X_{it} + v_{it} \quad (12)$$

$$v_{it} = \alpha_i + v_{it} \quad (13)$$

Where α_i represents a cross section-specific effect and that of v_{it} denotes the error term. Similarly, the random effect model was estimated to identify the relationship between economic growth and renewable energy consumption. With the random effect model, both the intercept and the coefficients vary across sections.

$$Y_{it} = \beta X_{it} + u_{it} \quad (14)$$

$$u_{it} = \alpha_i + v_{it} \quad (15)$$

Where i = 1 ……….N and t = 1,2……..T and E(X_{it}, α_i) = 0. Following these two models, the Hausman test was conducted to identify which of the two models is appropriate. The null hypothesis of the Hausman test says that, the Null hypothesis is appropriate. The EVIEWS computer software version 20.0 was used for the analysis and testing of the hypotheses.

3. Results and Discussion

In order to proceed with further analysis of the data in line with the objectives of the study, the unit root test was conducted to identify the order of cointegration of the Variables (LNGDP, RE, and RELECT) used. With this panel unit root test, five main tests Levin, Lin and Chu panel unit root test, Breitung test, and Im, Pesaran and Shin W-stat, ADF Fisher chi-square and PP Fisher chi square were performed and results present in Table 1 below.

Table 1.0 Results From Panel Unit Root Test

VARIABLES		LLC	Breitung	IPS	ADF-Fisher	PP-Fisher
		t-statistics	**t-statistics**	**w-statistics**	**Chi-square**	**Chi-square**
LEVEL (C &T)	LNGDP	-1.76484** (0.0388)	2.28681 (0.9889)	0.02714 (0.5108)	19.6922* (0.0731)	15.6899 (0.2059)
	RE	0.34953 (0.6367)	0.20272 (0.5803)	-0.02065 (0.4918)	12.4704 (0.4087)	13.9162 (0.3061)
	RELECT	-0.42470 (0.3355)	0.02854 (0.5114)	-0.37810 (0.3527)	15.9063 (0.1956)	16.5113 (0.1689)
FIRST DIFF. (C&T)	LGDP	-6.23749*** (0.0000)	-4.2489*** (0.0000)	-4.84445*** (0.0000)	43.3678*** (0.0000)	59.7914*** (0.0000)
	RE	-6.32870*** (0.0000)	0.37991 (0.6480)	-5.13578*** (0.0000)	46.1458*** (0.0000)	44.8505*** (0.0000)
	RELECT	-9.90180*** (0.0000)	-7.2272*** (0.0000)	-8.90765*** (0.0000)	79.0470*** (0.0000)	188.379*** (0.0000)

Note: IPS - Im, Pesaran and Shin W-stat, LLC - Levin, Lin and Chu t, *, ** and *** denote 10%, 5% and 1% level of significance correspondingly while C & T implies Constant individual intercept and Trend respectively.

Among all these tests, the unit root was first checked at levels with intercept and Trend and also secondly, at first difference with intercept and trend. The null hypothesis assumes that the each of the variables has a common and individual unit root or not stationary. At levels all the variables under the five tests were statistically significant meaning that, they were non-stationary or not I(0) at 5% level of significant. However, all the variable became stationary at first difference under all the five tests which implied that, all the variables were integrated at order one in other words I(1). This allowed for further testing of cointegration to check whether the equations are cointegrated or the variables have long run-relationships. The cointegration tests were conducted by employing the Kao Residual panel cointegration test and the Johansen Fisher combined Panel Cointegration tests and the results from these tests presented in Table 2 and 3 below correspondingly.

Table 2 Kao Residual Cointegration Test

SERIES	ADF t-statistics	Prob.
LNGDP, RE, RELECT (model 1)	-3.286993***	0.0005

Null hypothesis: no cointegration, *** denotes significance at 1%.

Results from the Kao residual test show that, reject the hypothesis of no cointegration even at 1% level of significance. This implies that, there is long run relationship between Economic growth (LNGD), Renewable energy consumption (RE) and renewable electricity output (RELECT) produced. The results from Johansen Fisher combined panel cointegration test in Table 3 below also confirmed the long run cointegration of the variable. The results rejected the null hypothesis of no cointegration at 1% level of significant but support that the hypothesis of existence of at most 1 or 2 cointegration (see Table 3 below).

Table 3 Johansen Fisher combined panel cointegration test (Model 1: LNGDP-(RE, RELECT)

Hypothesized No. of CE(s)	Fisher stat* Trace tset	Prob.	Fisher stat* Max-Eigen test	Prob.
None	39.40***	0.0001	41.19***	0.0000
At most 1	11.55	0.4826	9.541	0.6561
At most 2	9.658	0.6459	9.658	0.6459

Note: *** represents significant level of 1%.

The confirmation of long run cointegration implies that, the cointegration relationship can further be estimated. As advised by (Kao, 1999; Pedroni, 1999) and (Pedroni, 2001), both the Panel Dynamic Ordinary Least squares (DOLS), and panel Fully Modified Ordinary Least squares (FMOLS) were utilized for the estimation of the cointegration coefficients. The estimates from both FMOLS and DOLS established a statistically significant long run relationship between renewable energy consumption and economic growth. And the results from both estimates were consistent with each other and that of literature. The results are presented in Table 4

Table 4 Results from Cointegration estimations (Panel FMOLS and DOLS)

Dependent variables		Independent variables			
		Heterogeneous Long run coefficients		Homogeneous Long run coefficients	
		RE	RELECT	RE	RELECT
LNGDP Model 1	FMOLS	-0.043573*** (-14.32517)	-0.008808*** (-4.046990)	-0.044091*** (-19.83102)	-0.009858*** (-3.630941)
	DOLS	-0.039930*** (-10.57908)	-0.012600*** (-3.772614)	-0.039930*** (-16.58240)	-0.012600*** (-4.187457)
RE Model 2		LNGDP	RELECT	LNGDP	RELECT
	FMOLS	-19.66949*** (-13.99400)	-0.174446*** (-3.071242)	-19.56761*** (-19.57874)	-0.194798*** (-3.433354)
	DOLS	-20.32635*** (-19.29453)	-0.321879*** (-4.456403)	-20.32635*** (-19.65469)	-0.321879*** (-5.035875)

Note: *** implies 1% significant level and values in parenthesis represent t-statistics

Results from the FMOLS suggest that, there is a significant but negative long run relationship between renewable energy consumption and economic growth among the countries selected for the study. The findings indicate that, 1% increase in Renewable energy consumption will reduce economic growth by 0.044% in the long run. Similarly, increase in electricity output by 1% will results in a reduction I economic growth by 0.0098%. From the second model, 1% increase in economic growth causes a further significant reduction in renewable energy consumption by 19.5%-19.67% decreeing the electricity output from renewable sources by 0.174%-0.195%

On the other hand, results from the DOLS estimates are also consistent with that of the FMOLS by emphasizing the negative long run relationship between economic growth and renewable energy consumption and electricity output from renewable sources. The estimates gain establish that, 1% increase in renewable energy consumption contribute to a reduction of 0.0399% in economic growth while 1% increase in electricity output from renewable energy consumption reduces economic growth by 0.0126%. While in model 2, a further 1% increase in economic growth significantly reduces the renewable energy consumption by 20.33% and decreases electricity output from renewable sources by 0.32%.

This mixed effects coupled with the negative relationships must be interpreted with caution. The negative impact of renewable energy consumption on economic among the countries selected gives a clear picture of the situation of among the countries in the Central African Sub-regions where renewable energy resources is abundant and forms the major source of their energy consumption. Renewable energy resources such as large-scale biomass energy, small-scale biomass energy, solar photovoltaic, solar thermal; and wind, hydro power are available in their large quantities yet they are not used to benefit majority of the populations in the regions. Upon all these renewable energy available, only small proportion of the people have access to the renewable energy which minimizes its contribution to electricity.

This study supports the findings by (Karekezi, 2002; Neitzel, 2017; Wolde-Rufael, 2005)who also reported a negative relationship long run relationship between economic growth and renewable energy consumption in renewable energy resources abundance countries. The Central African Sub-regions particularly Cameroon, Gabon, Equatorial Guinea, Congo, Chad and Democratic Republic of Congo have abundance of renewable energy resources which constitute their major sources of Electricity and energy. However, the technology and cost involved in installing and the exploitation these renewable energy resources to benefit the people is always high as such electricity consumption is limited to the few high income earners in the cities.

This explains why only small proportion of their population have access to electricity. For example, only 13%, 13.5%, 58.8%, and 56% of the population have access to electricity in Central African Republic, DR Congo, Cameroon, and Congo respectively (WDI, World Bank, 2015). The cost involved in utilizing the renewable energy resources absorb a greater proportion of their GDP and this situation cost has contributed to the neglect of especially those in the rural part from benefiting from electricity. This confirms (Karekezi, 2002) who also found that in Africa only few population have access to electricity , for example less than 10% of the sub Saharan African population have access to electricity. And also found that, with this number, the electricity consumption is limited to those in the urban centers with high income levels. The electricity accessible to the poor and those in the rural areas is inadequate and several of the population in the rural areas without electricity continue to increase. Since the use of renewable energy is highly expensive, they are not mostly directed to support industrial productivity which may contributes to economic growth.

This findings can also be attributed to the fact that, as a growing economies, there can be managerial obstacles, political instability, inadequate allocation of resources, wide spread of poverty, inefficient utilization of the renewable energy as well as infrastructural deficits(Squalli, 2007). All these have a severe negative effect on rural industries and agriculture and their contributions to economic growth while the reverse also holds. The results from the causality test has also been presented in Table 5 below to demonstrate the flow of causation between the variables.

Table 5 Pairwise Dumitrescu-Hurlin Panel Causality Tests

Null hypothesis	W-statistics	Prob.
RE does not homogeneously cause LNGDP	1.70533	0.6058
LNGDP does not homogeneously cause RE	5.80676	0.0005***
RELECT does not homogeneously cause LNGDP	1.41279	0.4232
LNGDP does not homogeneously cause RELECT	2.28316	0.0462**

Note: ***, ** indicates 1% and 5 level of significance respectively

The direction of movements of the causation in this long run relationships between economic growth and renewable energy consumption has been estimated by the Pairwise Dumitrescu-Hurlin Panel Causality in the study (from Table 5). The causality test results in Table 5 show that, Economic growth causes renewable energy consumption and electricity output from renewable sources in the countries studied. The findings support the conservative hypothesis though it demonstrate uni-directional causation.

The results reveal that, economic growth causes renewable energy consumption well as electricity output from renewable sources and these linkages and direction of movement were significant at 1% and 5% respectively. This implies that any policy to strengthen the consumption of renewable energy may not have any negative severe impact on economic growth(Karekezi, 2002; Neitzel, 2017; Wolde-Rufael, 2005). This intuitively implies that the environment can be protected from Carbon emission from the consumption of nonrenewable energy, while sustainable development and future energy security can also be achieved.

The findings from the cointegration and causality analysis have also been supported from fixed effect penal data analysis approach. The results from the Hausman test which assumes a null hypothesis that random effect model is appropriate was rejected. The result from the Husman test is presented in Table 6

Table 6 Hausman test

Test summary	Chi-square statistics	d.f	Prob.
Cross-section random	7.7537**	2	0.020

Null hypothesis: Random Effect model is appropriate

The results from Table 6 allows the fixed effect model to be used to examine the impact of renewable energy consumption, electricity output from renewable resource on economic growth(see Table 7).

Table 7 Results from Fixed effect model

Independent variables	**Coefficient**	**t-statistics**	**Prob.**
C	26.70417***	148.7155	0.0000
RE	-0.044084***	-29.88769	0.0000
RELECT	-0.008470****	-4.610027	0.0000

Note: *** indicates 1% level of significance

Findings from the Table.l 7 also confirm the results from Table 4 & 5. The results show that, 1% increase in renweable reduces ecenomi growth by 0.044%. Simailrlry, 1 percent in output of electricity fon renewable sourcse reduces economic growth by 0.008%. This findings implicate the need to promote renewable energy consumtpion and renewable electricity production in the sub-region while utiliaing efficient technologies and minising the cost. This expansion should also benefit the rural areas to catlsys rural inductrializtaion and boost agriculture and entrepreneurship as well.

4. Conclusion and Policy Implications

This paper applied the Pannel cointegrtion approach to investigate the causal relationstionship bewteen renwable energy and econmic growth among Central African countries using data from world Bank WDI covering the period of 1990-2015. Results from the study revealed that, renewable energy consumtption and electricity output from renewable energy sourcses have negative relationship with economic growth both in the short run and long run. The findings also suggest that, the causal effect moves from economic growth to renewable energy consumption represnting a unidirectionanal and this findigs support the conservative hypothesis.

This results can be accounted by several factors.To borrow the words of Squila, the Central African Countries as a growing economies, are encountered by some managerial obstacles, political instability, inadequate allocation of resources, wide spread of poverty, inefficient utilization of the renewable energy as well as infrastructural deficits. The implication is that, eventhough renewable energy resources are aboubdnace in central African Sub-regions, they are not efficiently utilied to fully benefit the people. More importantly, most of the countries in the central Africa depend soly on renewable energy and greater proportion of their electricity come from the renewable energy cources however due to the high cost of installation of renewable energy technologies, nd widespread of poverty, only small share of their populations have access to electricity for production. Inspite of this, the majority of those who have access to electricity are in the cities and largely into the service sectors which contribute less to GDP.

The Rural populations and even significant numbers of urban dwellers do mot have aacces to electricity and this affect productivity and particulalry rural industries and agriculture. The abubdance of Renewable energy which is supposed to benefit the people positively is rather impacting negatively due to some constriants in terns of technology and cost to expand them.

Policies which will be dierected towords developing technologies to lower cost of installing and producing renewable energy would contribute positively to economic growth while protecting the enviorment against polution from green house gasses among others. Again, the governments, investor and NGOs should increase the investment in expanding the coverage of electricity from the renewable sources to rural areas and the urban centers to caatalyse industrial activites and Agriculture which have high potetial to propel econmic growth so that a sustainable development can be achieved and econmic growth can also have positive impact of the use of renewable energy in the regions.

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