*Review Article*

# Renewable and Non-Renewable Energy Consumption and Economic Growth- A Case of Nigeria

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***Abstract -*** *The study examines the relationship between renewable and non-renewable energy consumption and economic growth in Nigeria from 1984 to 2015, deploying the Autoregressive distributive lag model (ARDL) approach and the Vector autoregressive (VAR), the Granger Causality test was estimated and confirmed with the Wald test. The overall findings suggest the absence of causality, which supports the neutral hypothesis and the presence of a positive relationship between non-renewable energy consumption (NREC), renewable energy consumption (REC), and economic growth (GDP), both in the short run and long run. The study indicates that NREC and REC significantly stimulate economic growth in Nigeria. The positive relationship between the three variables implies that an increase in energy consumption is a strong determinant of economic growth. The policy consequences suggest the need for Nigeria to improve its energy supply mix and consumption, especially regarding renewable energy, because of environmental and climate change considerations by ensuring the implementation of the 2015 National Renewable Energy and Energy Efficiency Policy (NREEEP) without fear of jeopardizing economic growth.*

**Keywords -** *Economic Growth, ARDL, VAR, Renewable Energy Consumption, Non-renewable Energy Consumption.*

## I. INTRODUCTION

Energy is a vital element for economic growth and is generally viewed as the stimulus for most economic activities. The role of energy is equally important in income generation and employment. The global increase in demand for oil and carbon emissions with its attendant climatic and environmental degradation problems has continued to shape the renewed efforts to harness renewable energy sources. Meanwhile, the Oil crisis of the 1970s greatly threatened economic and political stability throughout the global economy. However, in very recent years, governments across the globe have intensified efforts to boost energy supplies due to growing demands (Onakoya et al., 2013).

Energy generated from renewable and non-renewable sources has become an important factor in improving living standards and has played a pivotal role in scientific and technological progress. As a result, energy is a key basis for economic growth. Presently, Nigeria is not an energy-intensive country. To meet its rapidly-increasing energy demand, Nigeria needs to urgently tackle the persistent energy issues that impede its industrialization process and economic growth. According to Iwayemi (2008), this situation has weakened the increased competitiveness of local industries in the global markets and consequently reduced employment generation. To achieve energy demand sufficiency, Nigeria must tackle the lingering energy emergency. Stern & Cleveland (2004) pointed out the need to pay attention to the impact of oil and related energy prices on economic activity and the role of energy or other natural resources as enablers of economic growth.

As the giant of Africa, Nigeria has been the focus of the world for its peculiar Gross Domestic Product (GDP) and Energy demand growth in recent years. The Nigerian Economic Outlook (2014) statistical data indicates that the Nigerian economy has had an average growth rate of over 6% in the last few years. It also records that the Economy grew at a rate of 5.3% in 2011, 4.2% in 2012, exceeded 5.5% in 2013, and 7.4% in 2014 (Alege et al., 2016).

It is expedient to note that for any energy-dependent country where causality runs from energy consumption to growth, policymaking should be carefully handled to ensure that negative energy shocks do not cause terrible damage to the economy. It is crucial to determine the causal relationship between energy consumption and other economic activities in such a case.

However, to decide on which direction it should follow in terms of energy (non-renewable and renewable) strategic outlook and economic growth, this work will attempt to study the trend analysis of energy (renewable and non-renewable) consumption in Nigeria; examine the relationship between energy (renewable and non-renewable) consumption both in the short run and long run, and economic growth in Nigeria and make policy recommendations based on the analysis.

Against this backdrop, this study examines the relationship between renewable and non-renewable energy consumption and economic growth in Nigeria from 1984 to 2015 using the Autoregressive distributive lag model (ARDL) approach. The objectives, amongst others, include:

1. To study the trend analysis of energy (renewable and non-renewable) consumption in Nigeria.
2. To examine the relationship between energy (renewable and non-renewable) consumption and economic growth in Nigeria.
3. To make policy recommendations based on the analysis from the study results.

## II. LITERATURE REVIEW

The connection between energy consumption and economic growth has generated so much interest over the years. Kraft and Kraft, 1978 started the first study of the causal relationships between forms of energy and economic growth in which causality was found to run from Gross National Product (GNP) to energy consumption in the United States. The link between economic growth and energy consumption has an important policy consequence. Ojinnaka (1998) shows that energy consumption trails national products and that the scale of energy consumption per capita is an important pointer to economic transformation. Practically, high energy consumption per capita countries are generally more developed than those with a low level of energy consumption.

In their study, Bello, Dalhatu & Dahood (2018) examine energy consumption and economic growth in Nigeria for thirty (30) years. The study proves that the power sector is an important instrument used by the government to improve the economy and that improvement of the power supply has strengthened all sectors of Nigeria's economy and greatly reduced economic retardation. The study's findings conclude that energy consumption has a significant correlation with economic growth in Nigeria.

Onakoya et al. (2013) evaluate the causal connection between energy consumption and economic growth in Nigeria from 1975 to 2010, using co-integration and ordinary least square techniques. The result indicates that total energy consumption had a similar movement with economic growth in the long run except for coal consumption. The empirical results reveal that petroleum, electricity, and total energy consumption have a significant and positive relationship with economic growth in Nigeria.

Interestingly, Mustapha & Fagge (2015) re-examine the causal relationship between energy consumption and economic growth using Nigeria’s data from 1980 to 2011. The causality analysis, which included labor and capital in a multivariate framework, informed the absence of causality. However, the variance decomposition test establishes that capital and labor affected output growth more than energy consumption.

Orhewere & Machame (2011) study the relationship between energy consumption and economic growth by investigating the causality between GDP and each of the subcomponents of energy consumption in Nigeria. The idea was to find out if different energy sources have varying impacts on economic growth. The study results discovered a unidirectional causality from electricity consumption to GDP both in the short-run and long-run, unidirectional causality from Gas consumption to GDP in the short-run, and bidirectional causality between the variable in the long run. There was no causality in any direction between oil consumption and GDP in the short run. On the other hand, a unidirectional causality from oil consumption to GDP was discovered in the long run.

Fotourehchi (2017) analyzes the long-run causality relationship between renewable energy consumption and economic growth for the period 1990-2012 for over forty developing countries. The study was carried out using the Canning and Pedroni (2008) long-run causality test, and it discovers a long-run positive causality running from renewable energy to real GDP.

In the study, Ranjan et al. (2017) examine the relationship between energy consumption and economic growth for Brazil, Russia, India, China, and South Africa (BRICS) countries within a multivariate panel framework for 1990 to 2012. The results show a long-run relationship among GDP per capita, renewable energy consumption, non-renewable energy consumption, and gross fixed capital formation and unidirectional causality from economic growth to renewable and non-renewable energy consumption, supporting the conservation hypothesis. The results indicate that economic growth is a significant stimulus for energy consumption for the BRICS countries. Therefore, higher economic growth will result in higher energy consumption and vice versa.

Most literature looked at energy consumption in terms of fossils and electricity, but Guía (2018) investigates the causality between renewable energy consumption (REC), non-renewable energy consumption (NREC), and economic growth for BRICS countries. The empirical results confirm a long-run relationship. Granger-causality results show a bidirectional relationship between REC and GDP, and TFEC and GDP in both the short-run and long-run, while NREC-GDP supports the growth hypothesis in the long-run and neutral hypothesis in the short-run.

### *A. Renewable Energy Potentials and Consumption in Nigeria*

The popular perception of renewable energy in Nigeria focuses mostly on solar and occasionally on wind power. Meanwhile, available data suggest that Renewables have a relatively short history in Nigeria, especially in public view. Even though hydropower has been at the core of Nigeria’s grid electricity production since the 1960s, only two hydropower stations were constructed, the Kanji and Jebba Dams (1300MW), which account for half the capacity of Nigeria’s stable power sources. The small but growing solar energy has delivered far greater stability in service than comparable interventions. Solar energy has contributed greatly to rural and non-grid areas in Nigeria.

Despite that Nigeria boasts of an abundance of renewable energy sources, the country has not shown remarkable progress in its development and use. This slow pace may be attributed to the initial high cost of capital for the development of renewable resources when compared to costs associated with fossil-based fuels. Increasing the amount of renewable energy in the energy mix requires that exploiting these resources be made economically-attractive (Nwagbo, 2017). Nonetheless, with an abundance of renewable resources and solid government support, the ability for Nigeria to incorporate renewable energy into its power grid is constantly increasing. In 2015, renewable energy consumption as a percentage (%) of total final energy consumption in Nigeria was 86.64%, according to the World Bank.

### *B. Nigeria`s GDP Profile*

The GDP measures the national income and output for a given country's economy. The gross domestic product (GDP) equals the total expenditures for all final goods and services produced within the country for a specific period. Consequently, the gross domestic product reflects the basic economic performance. The total of all goods and services sold worldwide gross domestic product in 2017 was estimated at 10.565 US Dollars per capita, whereas the GDP in Nigeria recorded 1.968 US Dollars per capita. According to World data, Nigeria's GDP progressed 2.0 percent year-on-year in the first quarter of 2019, easing from a 2.4 percent expansion in the previous period and below market expectations of 2.1 percent, mainly due to a steeper contraction in the country's oil sector.

The mean GDP Annual Growth Rate in Nigeria from 1982 until 2019 was 3.83%, reaching an all-time high of 19.17% in the fourth quarter of 2004 and a record low of -7.81% in the fourth quarter of 1983. Nigeria's Gross Domestic Product (GDP) was worth 397.30 billion US dollars in 2018 and represented 0.64% of the world economy. GDP in Nigeria averaged 125.26 USD Billion from 1960 until 2018, reaching an all-time high of 568.50 USD Billion in 2014 and a record low of 4.20 USD Billion in 1960.

## III. METHODOLOGY

### *A. Data*

For this study, annual time series data of GDP per capita and NREC from 1984 to 2014 and 1990 to 2014 of REC for Nigeria were employed. The data for the three variables are from the World Bank Development Indicators.

### *B. Model*

The model for the study is:

GDP= f(NREC, REC) (1)

GDP per capita is Current 2019 US$, NREC is non-renewable energy consumption (NREC) expressed as Fossil Fuels Energy Consumption (% of total), and REC is the renewable energy consumption (REC), measured in terajoule (TJ) as % of Total Final Energy consumption. To estimate the relationship between the variables, the linear logarithm is adopted.

In this Paper, the Bounds co-integration test is employed to test for the existence of co-integration. From the Bounds cointegration test result, if the variables are cointegrated, specify both short-run Autoregressive Distributive Lag (ARDL) and long-run Vector Error Correction Model (VECM). However, if the variables are not cointegrated, only the short-run (ARDL) is specified. The ARDL model is relatively more efficient in the case of small and finite sample data sizes. By applying the ARDL method, the results will show unbiased long-run estimates. The Autoregressive Distributive Lag model (ARDL) contains the lagged value(s) of the dependent variable and the current and lagged values of the regressor as explanatory variables. The ARDL uses a combination of endogenous and exogenous variables. It is used to test for unit root to verify that no variable integrates Order 2. ARDL models are usually specified.

The underlying test equation for the Bounds cointegration test is the ARDL (p, q) model as specified below:

$$y_t = \alpha + \sum_{I=1}^{p} \rho_i y_{t-i} + \beta X_t + \sum_{T=1}^{q} \Upsilon_t X_{t-j} + \varepsilon_t \qquad (2)$$

Where p is the lag length for $y_t$ (dependent variable) and q is the lag length for $X_t$ (regressor)

$$Y_t = \alpha + \sum_{I=1}^{p} \rho y_p + \beta X_q + \sum_{T=1}^{q} \Upsilon_t X_q + \varepsilon_t \qquad (3)$$

$Y_t$ Is a vector (the variables are allowed to be dependent) and the variables in (X'$_t$)' are allowed to be purely I(0) or I(1) or cointegrated: ρ and ʏ are coefficients, α is the constant; i= 1,…..k, p, q are optimal lag orders; $\varepsilon_t$ is a vector of the error terms. To perform the Bounds test for cointegration, the conditional ARDL (p, $q_1$, $q_2$) model with three variables (lnGDP, lnNREC, lnREC) is specified as:

$$\Delta \ln GDP_t = \alpha_{01} + b_{11} \ln GDP_{t-i} + b_{21} \ln NREC_{t-1} + b_{31} \ln REC_{t-i} + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{q} \alpha_{21} \Delta \ln NREC_{t-1} + \sum_{i=1}^{q} \alpha_{31} \Delta \ln REC_{t-1} + \varepsilon_{1t} \qquad (4)$$

$$\Delta \ln NREC_t = \alpha_{02} + b_{12} \ln GDP_{t-i} + b_{22} \ln NREC_{t-1}$$

$$+b_{32}\ln REC_{t-i}+\sum_{i=1}^{p}\alpha_{1i}\Delta\ln NREC_{t-i}$$
$$+b_{33}\ln REC_{t-i}+\sum_{i=1}^{p}\alpha_{1i}\Delta\ln REC_{t-i}$$
$$+\sum_{i=1}^{q}\alpha_{21}\Delta\ln GDP_{t-1}+\sum_{i=1}^{q}\alpha_{31}\Delta\ln REC_{t-1}$$
$$+\varepsilon_{3t} \quad (5)$$

$$\Delta\ln REC_{t}=\alpha_{03}+b_{13}\ln GDP_{t-i}+b_{23}\ln NREC_{t-1}$$
$$+b_{33}\ln REC_{t-i}+\sum_{i=1}^{p}\alpha_{1i}\Delta\ln REC_{t-i}$$
$$+\sum_{i=1}^{q}\alpha_{21}\Delta\ln GDP_{t-1}+\sum_{i=1}^{q}\alpha_{31}\Delta\ln REC_{t-1}$$
$$+\varepsilon_{3t} \quad (6)$$

Each variable can be specified as a dependent variable.

If there is no cointegration, the ARDL (p, $q_1$, $q_2$) model is specified as:

$$\Delta\ln GDP_{t}=\alpha_{01}+\sum_{i=1}^{p}\alpha_{1i}\Delta\ln GDP_{t-i}+\sum_{i=1}^{q}\alpha_{21}\Delta\ln NREC_{t-1}$$
$$+\sum_{i=1}^{q}\alpha_{31}\Delta\ln REC_{t-1}+\varepsilon_{t} \quad (7)$$

If there is cointegration, the Error Correction Model (ECM) is specified as the ARDL (p, $q_1$, $q_2$) model:

$$\Delta\ln GDP_{t}=\alpha_{0}+\sum_{i=1}^{p}\alpha_{1i}\Delta\ln GDP_{t-i}+\sum_{i=1}^{q}\alpha_{21}\Delta\ln NREC_{t-1}$$
$$+\sum_{i=1}^{q}\alpha_{31}\Delta\ln REC_{t-1}+\lambda ECT_{t-1}+\varepsilon_{t} \quad (8)$$

Where λ = speed of convergence, ECT= error correction term. The ECM model specification has both the short run equations showing their coefficients and the ECM, representing the long run representation. One lag is appropriate for the model. One of the basic features of a good ECM is that the coefficient must be negative. However, the coefficient of the ECM can be positive and statistically significant, depicting the nature of the long-run relationship. When the existence of co-integration relationships is confirmed, a comprehensive causality test based on an error-correction model (ECM) should be adopted (Engle & Granger, 1987). The outcome of the Bounds test indicates whether to specify a VECM, ECM, or ARDL model. The VECM is specified if there is cointegration from all three equations.

The Vector Autoregressive (VAR) method is used to estimate the lag lengths for both the short-run and long-run model specifications. The interpretation of the short-run coefficients is the ceteris paribus effects, and the conclusion is based on the usual Ordinary Least Squares (OLS) standard errors and test statistics. The short-run dynamic parameters are obtained by estimating a VECM or an ECM associated with long-run estimates. The ECM series are normally from the residuals of the long-run model, plugged into the model, and used to estimate the ECM. The ECM model specification has both the short run equations showing their coefficients and the ECM representing the long run representation.

One of the basic features of a good ECM is that the coefficient must be negative. However, the coefficient of the ECM can be positive and statistically significant, depicting the nature of the long-run relationship. The t-statistics on the explanatory variables (short-run coefficients) represent the short-run causal effect. The long-run relationship between the variables indicates that there is Granger- causality in at least one direction, which is determined by the t- statistics on the coefficient of the lagged error correction model. Post estimation tests conducted are Residual diagnostics using Serial correlation and Stability Diagnostics of the Walds test.

## IV. RESULTS AND DISCUSSIONS

### A. *Descriptive Statistics*

Table 1summarizes the basic statistical features of the data under consideration, including the mean, the minimum, and maximum values, standard deviation, skewness, kurtosis, and the Jarque-Bera test for the data. The descriptive statistics analysis of the three variables; GDP per capita, non-renewable energy consumption, and renewable energy consumption, is shown below:

**Table 1. Results of Descriptive Statistics**

| | GDP | NREC | REC |
|---|---|---|---|
| **Mean** | 1234.711 | 19.34710 | 86.28470 |
| **Median** | 741.3403 | 18.87677 | 86.44863 |
| **Maximum** | 3221.678 | 22.84479 | 88.83185 |
| **Minimum** | 270.0636 | 15.85414 | 82.95602 |
| **Std. Dev.** | 952.9985 | 1.750607 | 1.486974 |
| **Skewness** | 0.778410 | 0.322084 | -0.443640 |
| **Kurtosis** | 2.129691 | 2.372391 | 2.604349 |
| **Jarque- Bera** | 3.313675 | 0.842546 | 0.983131 |
| **Probability** | 0.190741 | 0.656211 | 0.611668 |
| **Sum** | 30867.79 | 483.6774 | 2157.117 |
| **Sum Sq. Dev.** | 21796948 | 73.55101 | 53.06620 |

The mean values are positive for the three variables; REC has the highest average of 86.28470, followed by NREC (19.34710) and GDP per capita (1234.711). There appears to be substantial variation, as shown by the large difference between the minimum and maximum values for GDP. In terms of Skewness which has to do with the spread of data, the results are; GDP (0.778410), NREC (0.322084), and REC (-0.443640). The spread of the insufficient available data for REC could be responsible for the negative value of the skewness.

### B. *Stationarity test*

The lnGDP, lnNREC, and lnREC were tested for stationarity using the ADF and PP tests. The results of the ADF and PP tests on the integration properties of real GDP per capita (lnGDP), non-renewable energy consumption (lnNREC), and renewable energy consumption (lnREC) are shown in Table 2 and Table 3, both in levels and first difference. The results of the two tests do not establish stationarity at level order I (0) of any of the series, indicating that lnGDP, lnNREC, and lnREC series are non-stationary at order zero. When lnGDP, lnNREC, and lnREC were tested on the first difference I (1), the results of the stationarity test, based on the ADF tests and PP tests, as presented in Table 3, shows that PP indicated a rejection of the null hypothesis of stationarity for all three variables whereas the ADF results established the presence of unit roots, the acceptance of the null hypothesis and consequently conditions of non-stationarity for all the variables. According to Table 3, for all the differentiated series, the ADF tests suggested non-stationarity for lnGDP, lnNREC, and lnREC, while PP tests suggested stationarity for all the variables. The results of the Probability values were also used as a guide to confirm the unit root tests.

**Table 2. Results of ADF and PP Unit Root Tests in Level I (0) Order of Integration**

| Variable | ADF Test | | PP Test | |
|---|---|---|---|---|
| | ADF test statistics | Critical value (5%) | Adj test statistics | Critical value (5%) |
| lnGDP | 0.9725 | -2.9810 | 2.5558 | 2.9639 |
| lnNREC | 2.5550 | 2.9810 | 2.6655 | 2.9634 |
| lnREC | 1.8557 | 3.0206 | 2.5504 | 2.9918 |
| Unit root test result | Non-stationarity | | Non-stationarity | |

**Table 3.Results of ADF and PP Unit Root Tests in the First Difference I (1) Order of Integration**

| Variable | ADF Test | | PP Test | |
|---|---|---|---|---|
| | ADF test statistics | Critical value (5%) | Adj test statistics | Critical value (5%) |
| lnGDP | 1.0750 | -2.9862 | 4.3130 | 2.9677 |
| lnNREC | 2.6272 | 2.9862 | 6.5536 | 2.9677 |
| lnREC | 1.7851 | 3.0299 | 5.1170 | 2.9980 |
| Unit root test result | Non-stationarity | | Stationarity | |

The ADF and PP tests used an intercept and no trend, and the lag length was chosen based on AIC. From the Unit test results of ADF and PP, they were non-stationarity at level and stationarity at first difference. The next step was to test for co-integration relationships between GDP, NREC, and REC. The presence of cointegration means both long-run and short-run relationships exist. The Bounds Cointegration test was employed as it is a more realistic approach since it allows for both I (0) and I (1) in a model. The Bounds cointegration test results established the presence of cointegration for only lnREC but no cointegration for lnGDP and lnNREC.

**Table 4.The Results of the Bounds Cointegration Tests**

| Dependent Variable | F-statistic value and t-stat | Cointegration | What next? |
|---|---|---|---|
| lnGDP | 1.643831<br>1.567378 | No | Estimate ARDL (Short-run model) |
| lnNREC | 2.755759<br>-1.293957 | No | Estimate ARDL (Short-run model) |
| lnREC | 4.883369<br>-2.801145 | Yes | Estimate ECM |

The Null hypothesis: If the F statistic value is below the I (0) bound, do not reject the null, but if the F statistic value is higher than I (0), reject the null hypothesis of no cointegration. As reflected in the table above, the results show that there existed a cointegration relationship when lnREC was the dependent variable. The absolute f-statistic value was below the I(0) bound; thus, the null hypothesis of the presence of cointegration was accepted. Furthermore, Error Correction Model estimation is required. However, in the case of lnGDP and lnNREC, there was no cointegration when used as a dependent variable. The implication is that only the ARDL model was used to estimate the short-run relationship for the two variables; lnGDP and lnNREC. To progress further on the Bounds cointegration test result, we specify the two short-run models for lnGDP and lnNREC and the long-run model for lnREC.

Model 1: Short-run model specifications

$$\Delta \ln GDP_t = \alpha_{01} + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{q} \alpha_{21} \Delta \ln NREC_{t-1} + \sum_{i=1}^{q} \alpha_{31} \Delta \ln REC_{t-1} + \varepsilon_t \quad (9)$$

**Table 5.Short Run Estimates for lnGDP Using ARDL and OLS Method**

| Variable | Coeff | Std Error | t- stat | Prob |
|---|---|---|---|---|
| C | 114.0283 | 40.9889 | 2.7819 | 0.0119 |
| D(LNGDP(-1)) | 0.1472 | 0.1974 | 0.7460 | 0.4648 |
| D(LNNREC(1)) | 70.2941 | 53.2560 | 1.3199 | 0.2025 |
| D(LNREC(-1)) | 126.8281 | 58.2719 | 2.1765 | 0.0423 |

The short-run model of lnGDP as the dependent variable indicates that lnNREC is not statistically significant, but lnREC is statistically significant at 5% level. The positive sign of the coefficients shows a positive relationship between the dependent variable, GDP, and independent variables NREC and REC in the short run. Hence, the higher the NREC and REC, the higher the GDP since the variables are directly related. The coefficient of determination of about 27% ($R^2$ =0.273018) indicates that the model's predictive power is poor, with the unexplained component accounting for about 73%. The overall model is not statistically significant, as presented by the F-statistic.

Model 2: Short-run model specifications

$$\Delta \ln NREC_t = \alpha_{02} + b_{12} \ln GDP_{t-i} + b_{22} \ln NREC_{t-1} + b_{32} \ln REC_{t-i} + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln NREC_{t-i} + \sum_{i=1}^{q} \alpha_{21} \Delta \ln GDP_{t-1} + \sum_{i=1}^{q} \alpha_{31} \Delta \ln REC_{t-1} + \varepsilon_{2t} \quad (10)$$

**Table 6. Short Run Estimates for lnNREC Using ARDL and OLS Method**

| Variable | Coeff | Std Error | t- stat | Prob. |
|---|---|---|---|---|
| C | -0.051822 | 0.306255 | -0.169212 | 0.8675 |
| D(LNREC(-1)) | 0.703190 | 0.468201 | 1.501899 | 0.1505 |
| D(LNGDP(-1)) | 0.001030 | 0.001499 | 0.686989 | 0.5008 |
| D(LNNREC(-1)) | -0.078789 | 0.407772 | -0.193219 | 0.8490 |
| ECM(-1) | -1.211658 | 0.415825 | -2.913865 | 0.0093 |

The short-run model of lnNREC as the dependent variable indicates that lnGDP and lnREC are not statistically significant; hence they do not affect NREC. The negative sign of the coefficients shows a negative relationship between the dependent variable, NREC, and independent variables GDP and REC in the short run. Hence, the higher the GDP and REC, the lower the NREC since the variables are indirectly related. A one percent increase in GDP will likely result in a 0.1116% decrease in NREC; a 1% increase in REC will likely indicate a 4627% decrease in NREC. The coefficient of determination of about 5.0% indicates that the model's predictive power is very poor since the unexplained component accounts for about 95%. The overall model is not statistically significant, as presented by the F-statistic.

Model 3: Long run model specifications

$$\ln REC_t = \alpha_{03} + b_{11} \ln REC_{t-i} + b_{21} \ln GDP_{t-1} + b_{31} \ln NREC_{t-i} + \varepsilon_{1t} \quad (11)$$

**Table 7. Long Run Estimate for lnREC**

| Variable | Coeff | Std Error | t- stat | Prob |
|---|---|---|---|---|
| C | 14.4163 | 24.6667 | 0.5844 | 0.5655 |
| LNREC(-1) | 0.7640 | 0.2476 | 3.0856 | 0.0058 |
| LNGDP(-1) | 0.0005 | 0.0003 | 1.4691 | 0.1573 |
| LNNREC(-1) | 0.2780 | 0.2188 | 1.2707 | 0.2184 |

The long-run relationship result indicates that GDP and NREC are not statistically significant; hence they do not affect REC. However, the positive sign of the coefficients shows that there is a positive relationship between the dependent variable, REC, and independent variables GDP and NREC in the long run. Hence, the higher the GDP and NREC, the higher the REC since the variables are directly related. A one percent increase in GDP will likely result in a 0.0463% increase in REC; a one percent increase in NREC will likely cause a 27.8% increase in REC. The coefficient of determination of about 40% indicates that the model's predictive power is below average since the unexplained component accounts for about 60%. The overall model is statistically significant at 5%, judging by the F-statistic.

Model 4: Error Correction Model (ECM) specifications

$$\Delta \ln REC_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln REC_{t-i} + \sum_{i=1}^{q} \alpha_{21} \Delta \ln GDP_{t-1} + \sum_{i=1}^{q} \alpha_{31} \Delta \ln NREC_{t-1} + \lambda ECT_{t-1} + \varepsilon_t \quad (12)$$

**Table 8. Error Correction Estimates**

| Variable | Coeff | Std Error | t- stat | Prob |
|---|---|---|---|---|
| C | -0.0665 | 0.3989 | -0.1668 | 0.8693 |
| D(LNNREC(-1)) | -0.3804 | 0.5183 | -0.7339 | 0.4720 |
| D(LNGDP(-1)) | -0.0011 | 0.0019 | -0.5809 | 0.5681 |
| D(LNREC(-1)) | -0.4628 | 0.5671 | 0.8161 | 0.4246 |

The ECM variable has a negative coefficient of -1.211658, which implies that the short-run variables approach long-run variables by 121% each year. It is statistically significant at 1%, which satisfies one of the conditions of a long-run relationship. The negative and significant value of the error correction term gives more evidence of a long-run and unidirectional relationship.

### C. *Stability Test*

The Walds test was employed to check for the stability of the various models, and the results show that the coefficients of the estimated models are stable as the graph of CUCUM and CUSUM statistics lies within the 5% critical bounds.

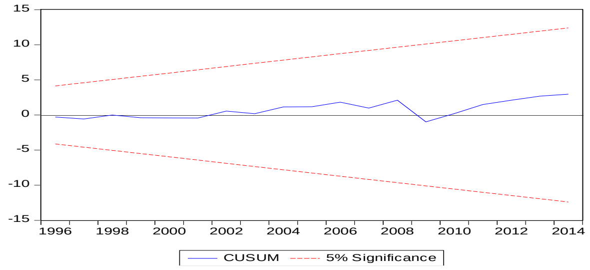


**Fig. 1 Stability Test Result for the Short-run Estimate for Dependent Variable lnGDP**

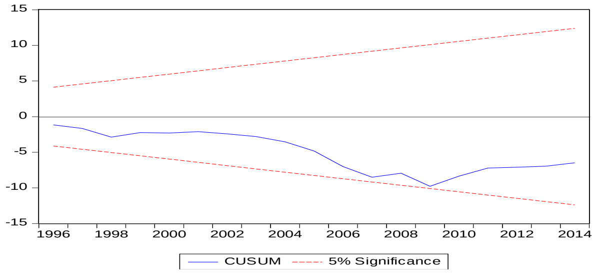


**Fig. 2 Stability Test Result for the Short-run Estimate for Dependent Variable lnNREC**

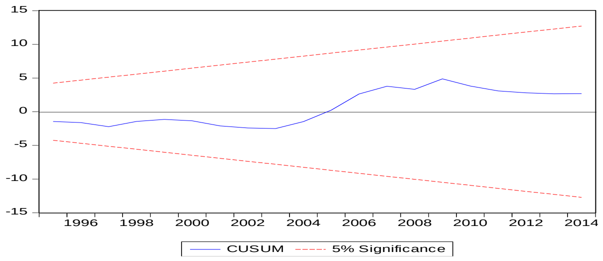


**Fig. 3 Stability Test Result for the Long-run Estimate for Dependent Variable lnREC**

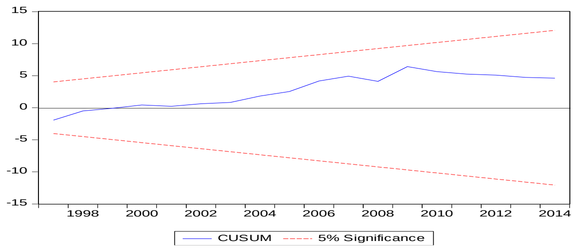


**Fig. 4 Stability Test Result for ECM Estimate**

**Table 9.Diagnostics Tests on the Original Model**

| Test Statistic | Result |
|---|---|
| Linearity | [t-statistic F(22)]= 0.939142 |
| Serial correlation | [F-statistic F(1,18)]= 66.71768*** |
| Normality | Jacque Bera= 1.956840 |
| Heterosckedasticity | [F-statistic F(1,22)]= 54.68950*** |

Note: *** @1% statistical significance.

The diagnostic tests revealed that the original model is linear since the computed t-stat is not significant. Also, there is the presence of serial correlation, which means that the model has to be re-specified to deal with the problem of serial correlation. The normality test indicated that the residual term appears to be normally distributed judging by the Jacque Bera stat.

### D. *Granger Causality Test*

Granger causality tests under the VAR environment were used to launch the Granger causality test. The short-run causality, if present, connect with policymaking in the short-run, and the long-run causality mainly influences strategic policymaking. Examining the coefficient of lnGDP (-1), the standard error, and t- stat, the t- stat value can be confirmed by dividing the coefficient by the standard error value. The unrestricted VAR is estimated by deploying all three variables as endogenous variables. The result is displayed below:

**Table 10. Results of Unrestricted VAR**

| Dependent variable: LNGDP | | | |
|---|---|---|---|
| **Excluded** | **Chi-sq** | **df** | **Prob.** |
| LNNREC | 1.358323 | 2 | 0.5070 |
| LNREC | 4.897733 | 2 | 0.0864 |
| **Dependent variable: LNNREC** | | | |
| **Excluded** | **Chi-sq** | **df** | **Prob.** |
| LNGDP | 1.193939 | 2 | 0.5505 |
| LNREC | 0.600138 | 2 | 0.7408 |
| **Dependent variable: LNREC** | | | |
| **Excluded** | **Chi-sq** | **df** | **Prob.** |
| LNGDP | 2.743750 | 2 | 0.2536 |
| LNNREC | 2.847326 | 2 | 0.2408 |

Interpreting the Granger causality result; the null hypothesis states that if P-value is greater than 5%, we cannot reject the null hypothesis but accept it; however, if otherwise, we reject the null hypothesis. With lnGDP as the dependent variable, the P-value of 50.70% and 8.64% for lnNREC for (-1) and (-2) and lnREC for (-1) and (-2) respectively are greater than 5%. Hence we accept the null hypothesis of no Granger causality running from the independent to the dependent variable. An examination of lnNREC as the dependent variable and joint lags of lnGDP and lnREC as independent variables indicated no Granger causality, as shown in the table. The same applies to lnREC as a dependent variable and others as independent variables. The P-value of 25.36% is greater than 5%, so we accept the null hypothesis of no Granger causality between the variables. The result established a case of no Granger causality in both the short-run and long-run between the GDP, NREC, and REC. The Granger Causality test result is cross-checked with the Wald test (System equation), and the results confirmed the non-existence of Granger causality between the variables as shown below:

**Table 11. Results of the Wald Test**

| Test Statistic | Value | df | Probability |
|---|---|---|---|
| Chi-square | 1.358323 | 2 | 0.5070 |

From the Table, P value= 0.5070= 50.70%, which is greater than 5%. We accept the null hypothesis of no causality. From the System equation, we have:

**Table 12. Results of the System Equation**

| Null Hypothesis: C(3)=C(4)=0<br>Null Hypothesis Summary: | | |
|---|---|---|
| **Normalized Restriction (= 0)** | **Value** | **Std. Err.** |
| C(3) | 8.995265 | 62.53232 |
| C(4) | -42.32210 | 59.91796 |

## V. CONCLUSION

The paper has presented the empirical analysis of the dynamic relationship between non-renewable energy consumption, renewable energy consumption, and economic growth in Nigeria using time series data From 1984 to 2014 for non-renewable energy consumption and economic growth and annual data series from 1990 to 2014 for renewable energy consumption. The causality between non-renewable energy consumption, renewable energy consumption, and economic growth in Nigeria was investigated using the Granger causality in the VAR environment and the Wald test. The two methods confirmed the absence of causality. However, the short-run model of GDP as a dependent variable indicated a positive sign on the coefficients and consequently a positive relationship between the dependent variable, GDP, and NREC and REC in the short run. The overall findings suggest the absence of causality and the presence of a positive relationship between non-renewable energy consumption (NREC), renewable energy consumption (REC), and economic growth (GDP) both in the short and long runs. The study shows that NREC and REC significantly stimulate economic growth in Nigeria. The positive relationship between the three variables implies increased energy consumption is a strong determinant of economic growth. The policy consequences suggest the need for Nigeria to improve its energy supply mix and consumption, especially regarding renewable energy, by ensuring the implementation of the 2015 National Renewable Energy and Energy Efficiency Policy (NREEEP) without fear of jeopardizing economic growth. The author would like to point out the limitation encountered in the study in terms of data paucity for renewable energy consumption (REC) in Nigeria, whereas the other two variables of non-renewable energy consumption (NREC) and economic growth (GDP) had 30 observations, REC was only 24 observations. The insufficient observations for REC may have been too small to satisfy the asymptotics underlying the co-integration and causality tests. We recommend that future work be conducted on the research area when more data on renewable energy consumption in Nigeria is available.

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