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ASSESSING THE KEY DRIVERS OF ENERGY DEMAND IN NIGERIA: APPLICATION OF ARDL APPROACH

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Abstract

The study assessed the key determinants of energy demand in Nigeria using an Autoregressive Distributed Lag (ARDL) model and Vector Error Correction Model (VECM) covering the sample period of 1987 to 2017. The results from ARDL model indicates strong cointegration relationship among the variables and that CO2 emission and real GDP have significant positive impact on energy demand with Urbanization having significant negative and significant impact on energy demand in both long run and short run periods. The VECM Granger causality test results revealed that there is long run causality in access to electricity and CO2 emission equations and that there is also short run bidirectional causality running from real GDP to energy demand and from urbanization to real GDP. Short run unidirectional causality also exist running form CO2 emission to real GDP and from access to electricity to real GDP. Therefore, it is concluded that CO2 emission, real GDP and urbanization are among the key drivers of energy demand in Nigeria.

Keywords

Energy Demand, Urbanization, CO2 emission, ARDL Approach and VECM Granger Causality

1.0 Introduction

Energy plays a vital role in the functioning of the world economy. Spurred by the oil price shocks in late 1973 and during the period 1979 to 1980 until the recent oil price increased in 1999 and 2000, a lot of attention was devoted to the analysis of energy demand. As a consequence of the dramatic events in energy markets and the increasing importance of this sector in national economies, great effort was made to estimate the relationship between demand and its determinants such as income and price Azlina et al. (2013).

Population has been established as one of the key drivers of energy demand. According to the United Nations (UN) Population Division, global population is expected to increase from over 7.2 billion in 2014 to almost 9.0 billion in 2040. More than 90% of the rise in population is expected to come from developing countries. India is projected to be more populous than China in 2028. As a result, global GDP is projected to increase from 3.1% in 2014 to about 3.8% in 2018, led by the rapidly growing economies of developing countries. As population increase over time, the provision for better standards of living drives increase in energy consumption. Therefore, in the long-run, the impact of population growth, including changing age structures will have implications for energy demand and economic growth. Thus, the energy demand, which is projected to grow significantly by about 52.0% over the period 2010 through 2035, will largely be driven by population and economic growth in the non-OECD countries (EIA, 2014) as cited in (CBN, 2018).

Energy demand in Sub-Saharan Africa grew by around 45% from 2000 to 2012, but accounts for only 4% of the world total, despite being home to 13% of the global population. Access to modern energy services, though increasing, remains limited: despite many positive efforts, more than 620 million people in sub-Saharan Africa remain without access to electricity and nearly 730 million rely on the traditional use of solid biomass for cooking. Electricity consumption per capita is, on average, less than that needed to power a 50-watt light bulb continuously (IEA, 2014).

Pesaran et al. (1998) as cited in Azlina et al. (2013) highlighted that the empirical investigation of energy demand has been one of the most researched areas in energy economics. The energy demand specification is crucial input to any analysis of future energy usage and the impact of policy responses. According to Azlina et al. *(*2013) the global warming, which resulting from the emissions of carbon dioxide currently originates in the energy sector, where the principal source of greenhouse gas is the emission of CO_2 from the burning of fossil fuels, has highlighted focused attention on the pattern and the trend of energy demand. Therefore, accurately estimating and analyzing the determinants of energy demand scan some information for government as a basis of setting up appropriate policies related to environment such as pollution and energy taxes.

Another major concern in modeling energy demand study is the price volatility in international energy markets. Generally, the developing countries suffer more than the developed countries from energy price increases. The impact on growth in developing countries is thought to be significantly higher, because energy-intensive manufacturing generally accounts for a larger share of their GDP and energy is used less efficiently. The volatile energy markets can distort the mid-and long-term development path of the industry and even countries' economy as a whole.

Given the importance of energy role in economies, several studies have been carried out to apprehend the link between energy consumption and economic growth Fatiha and Karim (2019). These studies adopted several approaches, including short-term and long-term impact analysis and causality in determining the drivers of energy demand.

Within this framework, this study is intended to contribute to the existing debate on causal links between energy consumption, energy demand and other variables. In the case of Nigeria, as a developing country and the exporter and importer of most of its energy, it will provide a better perception of the mechanisms that act on the formulation of its energy demand.

As a result, the objective of this study is to empirically identify the key determinants of energy demand in Nigeria during the period of 1987 to 2017. The choice of the study period is justified by the availability of statistical data on all the variables in the model. The estimation method used is based on the autoregressive distributed lag model (ARDL) which gives both short run and long run coefficients.

To this end, the structure of this article will be distributed as follows: the first section is devoted to introduction, the second section will include the literature review, the third section will include data and methodology for analyzing the key determinants of energy demand and causal links, section four will be for results and discussions of findings. Finally, the final section, by way of conclusion, will be reserved for summary and conclusion resulting there from.

2.0 Empirical literature review

Since the industrial revolution that has been an upheaval for the economic world, economists have been interested in the link between energy and economic growth in theoretical literature; while several empirical works have been carried out in several countries, especially after the first oil shock in 1973, these studies have shown different results depending on the specific characteristics of each country and the methods used Fatiha and Karim (2019). The first empirical studies of causal relationships between energy and GDP were that of Kraft and Kraft (1978), in the United State (US) during the period of 1947 to 1974, the results of their study revealed that there is a unidirectional causality running from GDP towards energy demand. Ever since the publication of this study, several empirical studies surfaced with different methodologies and varying sample size to examine relationship and/or causality between energy use, trade openness, economic growth, population density, and CO_2 emissions, in different countries and regions of the world Sulaiman and Abdul-Rahim (2018). Some of these studies include Nasiru (2012), Ubi et al. (2012), Olusanya (2012), Ogundape and Apata (2013), Saqlain et al. (2013), Azlina et al. (2013), Okwanya and Abah (2018), Hassan (2018), Fatiha and Karim (2019), Kouton and Amonle (2019) and Musa et al. (2019).

Nasiru (2012) examines the relationship between coal consumption and economic growth for Nigeria over the period 1980 to 2010 using two-step residual-based approach to co-integration and granger causality test. The results revealed that there is long run relationship between coal consumption and economic growth. Also, the causality results indicate a unidirectional relationship running from economic growth to coal consumption.

Ubi et al. (2012) analyzed the determinants of electricity supply in Nigeria using secondary data from 1970 to 2009. Using Ordinary Least Squares (OLS), the results shows that technology, government funding, and the level of power loss were the statistically significant determinants of electricity supply in Nigeria and that an average of 40 percent of power is lost in transmission per annum.

Olusanya (2012) investigates the long run relationship between energy consumption and the economic growth in Nigeria from the period of 1985 to 2005. The study make use of secondary data analysis of ordinary least squares method and the revealed that petroleum, electricity are positively related to economic growth while coal and gas shows a negative relationship with economic growth of Nigeria. The study concludes that increased energy consumption is a strong determinant of economic growth having an implicit effect in lagged periods and both an implicit and explicit effect on the present period in Nigeria.

Ogundape and Apata (2013) examine the relationship between electricity consumption and economic growth in Nigeria using the Johansen and Juselius cointegration technique based on the Cobb-Douglas growth model covering the period of 1980 to 2008. Using vector error correction model and Pairwise granger causality test, the study found the existence of cointegrating relationship among the variables. Also, the study shows an evidence of bidirectional causality between electricity consumption and economic growth.

Saqlain et al. (2013) examines the causal relationship between coal consumption and economic growth in Pakistan. The study covers the period of 1974 to 2010. The direction of causality between the variables is investigated by applying the VECM granger causality approach. The findings have exposed that there exists bidirectional granger causality between economic growth and coal consumption.

Aziz et al. (2013) analyzed the determinants of energy demand by measuring the short run and long run relationship among energy demand, real gross domestic product, real energy price, industrialization and CO_2 emissions for 16 developing countries over the period of 1978 to 2003. With the ARDL approach, they manifested the findings, of which, one is the evidence of income, energy price, industrialization and CO_2 emissions to exert significant impact on energy demand over the long run.

Okwanya and Abah (2018) investigate the impact of energy consumption on poverty reduction in a panel of 12 African countries over a period of 1981 to 2014. Using the fully modified ordinary least squares (FMOLS) method, the result shows that there is a long run negative relationship between energy consumption and poverty level. The result also indicates that other variables such as capital stock and political stability have significant effect on poverty implying that these factors play critical role in reducing poverty. The granger causality test shows that a short-run unidirectional causality runs from energy consumption to poverty. It is concluded that increasing energy consumption leads to decline in poverty level.

Hassan (2018) investigates the interplay between energy demand and its determinants notably world oil price, economic growth, population, urbanization and energy access in the Association of Southeast Asian Nations (ASEAN)-5 over the 2000 to 2016 period. At the aggregated level, the long run results reveal that economic growth, energy access and urbanization have significant effects on energy demand. However, the results vary by the disaggregated fuel type, respectively.

Fatiha and Karim (2019) analyzed the determinants of energy demands in morocco during the period of 1990 to 2016. Using Error Correction (ECM) Model, the results shows that energy demand in morocco is linked to real causes, which are gross domestic products (GDP), access to electricity and foreign direct investment.

Kouton and Amonle (2019) investigate the impact of renewable energy consumption on economic growth in Cote d'Ivoire by using autoregressive distributed lag (ARDL) model. Using data covering the period of 1991 to 2015, the results suggest that in the short run, the impact of renewable energy consumption on economic growth is mixed while in the long run, the impact is not significant. The results also provide empirical evidence that the non-renewable energy/renewable energy transition is not yet effective but is under process in Cote d'Ivoire.

Musa et al. (2019) studied the impact of oil price and exchange rate on economic growth in Nigeria using ARDL approach to analyze the data for the period of 1982 to 2018. The result revealed that oil price and exchange rate have significant positive impact on economic growth in both the short run and long run period. The finding suggested that oil price and exchange rate could affect economic growth in both the short run and long run periods.

3.0 Data and Methodology

The Nigeria's annual data employed in this study ranges from 1987 to 2017. The data on Energy consumption, CO_2 Emission, Access to Electricity and Urban Population were sourced from world development indicators of World Bank while data on Real Gross Domestic Products was sourced from Central Bank of Nigeria.

To derive the model, we adopt and modify the model of Fatiha and Karim (2019) who study the impact of key determinant of energy demand in morocco. The model is given as $CE = f(PIB, ACCEL, IED)$. where: PIB is the proxy for gross domestic products, ACCEL is the access to electricity (% of the population), IED is the direct foreign investment. The modify model for this research work with additional variable is given as $ED = f(\text{RGDP}, \text{EA}, \text{URB}, CO_2)$.

Where: ED is the energy demand measured as Energy use (kg of oil equivalent per capita), $RGDP$ real gross domestic products (₦ 'Billions), AE is access to electricity ((% of population), CO_2 is carbon emission (Metric tons CO_2 per year), URB is the urbanization measured as urban population.

Following the above model, the econometric form of the model can be written in a simple logarithmic linear form. The reasons for transforming the model into logarithmic form include reducing the problems of multicollinearity, heteroscedasticity and provide easiest way of interpreting the variables in terms of elasticity coefficients and the model is given as follow:

$$\ln\text{ED}_t = \beta_0 + \beta_1 \ln\text{RGDP}_t + \beta_2 \ln\text{AE}_t + \beta_3 \ln\text{URB}_t + \beta_4 \ln\text{CO}_{2t} + \mu_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (1)$$

Where: $\ln\text{ED}_t$ stand in for the natural log of energy demand, β_0 is constant parameter, β_1-β_4 are the coefficients of independent variables, $\ln\text{RGDP}_t$ is the natural log of real gross domestic products, $\ln\text{AE}_t$ is the natural log of access to electricity, $\ln\text{URB}_t$ is the natural log of urbanization, $\ln\text{CO}_{2t}$ is the natural log of CO_2 emission, t is denoting time and μ disturbance term.

The stationarity of the variables utilized in this study is checked using the traditional Augmented Dickey Fuller unit root test (ADF), Philip Perron unit root test (PP) and compared their results using Breakpoint unit root test. The general form of equation for ADF and PP unit root tests are estimated as follow:

$$ADF \rightarrow \quad \Delta Y_t = \beta_0 + \beta_1 \chi_t + \sum_{t=1}^{k} \beta_1 \chi_t + \phi_t + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots... (2)$$

$$PP \rightarrow \quad \Delta Y_t = \beta_0 + \beta_1 \chi_{t-1} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where: Y is a time series, t is the linear time series trend, Δ is a first difference parameter, β_0 is the constant parameter, k is optimum lag length in the dependent variable and ε is the stochastic error term.

The ARDL bound approach has been employed to test for cointegration relationship among the variables of the study even though there are other methods for achieving the same objective, this method has several advantages that include; it is applicable in spite of the order of integration of the variables in the model (i.e., whether all variables are I(0), I(1) or mixture of I(0) and I(1);

ARDL gives short-run and long-run coefficients simultaneously; it's a good model for small sample size (i.e. 30-80 observations); ARDL has an indirect cointegration test within the model; and it composed of diagnostic tests within the model (e.g. using Microfit statistical software).

Based on these advantages, this study chooses this approach and formulated the conditional error correction model as follow;

$$\Delta \ln ED_t = \beta_0 + \sum_{i=1}^{k}\phi_{1i}\Delta \ln ED_{t-i} + \sum_{i=o}^{k}\chi_{1i}\Delta \ln RGDP_{t-i} + \sum_{i=0}^{k}\varphi_{1i}\Delta \ln AE_{t-i} + \sum_{i=0}^{k}\gamma_{1i}\Delta \ln URB_{t-i} + \sum_{i=0}^{k}\delta_{1i}\Delta \ln CO_{2t-i}$$
$$\alpha_1 \ln ED_{t-i} + \alpha_2 \ln RGDP_{t-1} + \alpha_3 \ln AE_{t-1} + \alpha_4 \ln URB_{t-1} + \alpha_5 \ln CO_{2t-1} + \mu_t \quad (4)$$

Where: ln is the natural log sign, β_0 is the constant parameter, ϕ, χ, γ *and* δ are the short run coefficients, $\alpha_1 - \alpha_5$ are the long run coefficients, k is the maximum lag length, t is the time and μ is error term while the rest as define above.

The estimated result for equation 4 is obtained using OLS method and to test for cointegration relationship among the dependent and independent variables by conducting a F-test to determine the joint significance of the lagged coefficients of the variables. To achieve this task, the null hypothesis if no cointegration in equation 4 is defined as H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$ as against the alternative hypothesis, which states that there is existence of cointegration (Ha : $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq 0$). To make decision on the result, Pesaran and Pesaran (1997) suggested that the estimated F-statistic should be compared with the critical values of lower bounds and upper bounds values. If the calculated F-statistic exceeds the upper bound critical values, cointegration relationship exists. If the calculated F-statistic lies in between the lower bounds and upper bounds values, the test result is said to be inconclusive. However, if the calculated F-statistic lies below the lower bound value, then no cointegration exist among the variables. Therefore, base on the existence of cointegration relationship from equation 4 above, the long run and short run ARDL models are specified in Equation 5 and 6 and estimated respectively to obtain the coefficients.

$$\ln ED_t = \beta_1 + \sum_{i=1}^{k}\phi_{2i}\ln ED_{t-i} + \sum_{i=0}^{k}\chi_{2i}\ln RGDP_{t-i} + \sum_{i=0}^{k}\varphi_{2i}\ln AE_{t-i} + \sum_{i=0}^{k}\gamma_{2i}\ln URB_{t-i} + \sum_{i=0}^{k}\delta_{2i}\ln CO_{2t-i} + \varepsilon_{2t} \quad (5)$$

$$\Delta \ln ED_t = \beta_2 + \sum_{i=1}^{k}\phi_{3i}\Delta \ln ED_{t-i} + \sum_{i=0}^{k}\chi_{3i}\Delta \ln RGDP_{t-i} + \sum_{i=0}^{k}\varphi_{3i}\Delta \ln AE_{t-i} + \sum_{i=0}^{k}\gamma_{3i}\Delta \ln URB_{t-i} + \sum_{i=0}^{k}\delta_{3i}\Delta \ln CO_{2t-i} + \vartheta ECT_{t-i} + \varepsilon_{3t} \quad (6)$$

The coefficient of error correction term (ECT) is denoted by ϑ and it measures the speed of adjustment of the variables toward long run convergence.

Lastly, this study diagnosed the model by conducting reliability tests for serial correlation (using Breusch-Pagan LM test), heteroscedasticity (using Autoregressive condition heteroskedasticity (ARCH) test for heteroscedasticity), Normality test (using Jarque-Bera test), functional form (using Ramsey RESET test) and stability test (using CUSUM and CUSUMSQ) to be able to assess how stable the model is along the sample periods.

3.1 Robustness check using dynamic OLS, fully Modified OLS and canonical CR

To gauge the long run estimates, we apply time series dynamic ordinary least square (DOLS), fully modified ordinary least square (FMOLS) and Canonical Cointegration Regression (CCR). DOLS, FMOLS and CCR have the power to tackle simultaneity bias, endogeneity problem, and small sample problem. These estimators are good for robustness check of ARDL estimates. DOLS, FMOLS and CCR have been advanced by Stock and Watson (1993), Philip and Moon (1999) and Park (1992) respectively to tackle the problem of small sample size and serial correlation accredited to Ordinary Least Squares (OLS) estimator. The estimators can also be applied to mixture of order of integrated variables in the presence of cointegration. Considering the powers of these estimators, their outcomes will serve as robustness checks to long run ARDL coefficients.

3.2 Vector error correction model (VECM) granger causality

Having found long run relationship between variables, the direction of causality between the variables is also tested using vector error correction model. Sulaiman and Abdul-Rahim (2018), Musa et al. (2020) maintain that VECM is considered to be more efficient in testing the direction of causality among the dependent and independent variables when the variables moved together in the long run. Again, the methodology is considered to be the best for testing causality among variables of the same order of integration, that is, when they variables are stationary at first difference meaning they are all I (1) variables. The vector error correction model (VECM) modeling equation within a system of error correction model (ECM) for this study is given in a matrix form below:

$$\begin{bmatrix} \Delta \ln ED_t \\ \Delta \ln RGDP_t \\ \Delta \ln AE_t \\ \Delta \ln URB_t \\ \Delta \ln CO_{2t} \end{bmatrix} = \begin{bmatrix} \phi_0 \\ \chi_0 \\ \varphi_0 \\ \gamma_0 \\ \delta_0 \end{bmatrix} + \sum_{i=1}^{k} \begin{bmatrix} \phi_{1i} & \phi_{2i} & \phi_{3i} & \phi_{4i} & \phi_{5i} \\ \chi_{1i} & \chi_{2i} & \chi_{3i} & \chi_{4i} & \chi_{5i} \\ \varphi_{1i} & \varphi_{2i} & \varphi_{3i} & \varphi_{4i} & \varphi_{5i} \\ \gamma_{1i} & \gamma_{2i} & \gamma_{3i} & \gamma_{4i} & \gamma_{5i} \\ \delta_{1i} & \delta_{2i} & \delta_{3i} & \delta_{4i} & \delta_{5i} \end{bmatrix} \times \begin{bmatrix} \Delta \ln ED_{t-1} \\ \Delta \ln RGDP_{t-1} \\ \Delta \ln AE_{t-1} \\ \Delta \ln URB_{t-1} \\ \Delta \ln CO_{2t-1} \end{bmatrix} + \begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \theta_4 \\ \theta_5 \end{bmatrix} \left(ECT_{t-1} \right) + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \end{bmatrix}$$

$$\Delta \ln ED_t = \phi_0 + \sum_{i=1}^{k} \phi_{1i} \Delta \ln ED_{t-1} + \sum_{i=1}^{k} \phi_{2i} \Delta \ln RGDP_{t-1} + \sum_{i=1}^{k} \phi_{3i} \Delta \ln AE_{t-1} + \sum_{i=1}^{k} \phi_{4i} \Delta \ln URB_{t-1} + \sum_{i=1}^{k} \phi_{5i} \Delta \ln CO_{2t-1} + \theta_1 ECT_{t-1} + \varepsilon_{1t} \quad \ldots\ldots (7)$$

$$\Delta \ln RGDP_t = \chi_0 + \sum_{i=1}^{k} \chi_{1i} \Delta \ln ED_{t-1} + \sum_{i=1}^{k} \chi_{2i} \Delta \ln RGDP_{t-1} + \sum_{i=1}^{k} \chi_{3i} \Delta \ln AE_{t-1} + \sum_{i=1}^{k} \chi_{4i} \Delta \ln URB_{t-1} + \sum_{i=1}^{k} \chi_{5i} \Delta \ln CO_{2t-1} + \theta_2 ECT_{t-1} + \varepsilon_{2t} \quad \ldots\ldots (8)$$

$$\Delta \ln AE_t = \varphi_0 + \sum_{i=1}^{k} \varphi_{1i} \Delta \ln ED_{t-1} + \sum_{i=1}^{k} \varphi_{2i} \Delta \ln RGDP_{t-1} + \sum_{i=1}^{k} \varphi_{3i} \Delta \ln AE_{t-1} + \sum_{i=1}^{k} \varphi_{4i} \Delta \ln URB_{t-1} + \sum_{i=1}^{k} \varphi_{5i} \Delta \ln CO_{2t-1} + \theta_3 ECT_{t-1} + \varepsilon_{3t} \quad \ldots\ldots (9)$$

$$\Delta \ln URB_t = \gamma_0 + \sum_{i=1}^{k} \gamma_{1i} \Delta \ln ED_{t-1} + \sum_{i=1}^{k} \gamma_{2i} \Delta \ln RGDP_{t-1} + \sum_{i=1}^{k} \gamma_{3i} \Delta \ln AE_{t-1} + \sum_{i=1}^{k} \gamma_{4i} \Delta \ln URB_{t-1} + \sum_{i=1}^{k} \gamma_{5i} \Delta \ln CO_{2t-1} + \vartheta_4 ECT_{t-1} + \varepsilon_{4t} \quad \ldots\ldots (10)$$

$$\Delta \ln CO_{2t} = \delta_0 + \sum_{i=1}^{k} \delta_{1i} \Delta \ln ED_{t-1} + \sum_{i=1}^{k} \delta_{2i} \Delta \ln RGDP_{t-1} + \sum_{i=1}^{k} \delta_{3i} \Delta \ln AE_{t-1} + \sum_{i=1}^{k} \delta_{4i} \Delta \ln URB_{t-1} + \sum_{i=1}^{k} \delta_{5i} \Delta \ln CO_{2t-1} + \theta_5 ECT_{t-1} + \varepsilon_{5t} \quad \ldots\ldots (11)$$

Where the error correction term's coefficients are represented by $\theta_1 - \theta_5$, the homoscedastic disturbance terms are denoted by $\varepsilon_1 - \varepsilon_5$, the error correction term is denoted by ECT_{t-1}. The ECT_{t-1} indicates the long run causality and the speed of adjustment toward long run equilibrium, while the Wald test statistic of the first difference of the variables shows the short run causality and its direction.

4.0 Results and Discussions

This section presents the results of the estimation and the discussions of the findings in relation to the present study. The descriptive statistics are presented in **Table 1** with the correlation analysis of the variables presented in **Table 2**. The descriptive statistics results revealed that the observations are equal meaning there are 31 numbers of observations. The mean values of these variables are; ED_t (654.259), AE_t (41.399), CO_{2t} (91.901), $RGDP_t$ (36247882) and URB_t (51741306). The Jarque-Bera probability values indicate that ED and AE are not normally distributed but CO_2, RGDP and URB are normally distributed. The analyses further indicate that, ED_t, AE_t CO_{2t} are negatively skewed while $RGDP_t$ and URB_t are positively skewed. The variability returned indicated by the standard deviation statistics indicates that ED_t (220.204), AE_t (15.690), CO_2 (10.369) $RGDP_t$ (187) and URB_t (2117). Comparatively, these values show that, all the variables are clearly dispersed far below their mean and median values.

Table 1: Descriptive Analysis of the variables

Variables	Obs	Mean	Median	Maxi.	Mini.	Std. Dev.	Skewness	Kurtosis	Prob.
ED_t	31	654.259	715.8626	798.6302	677.2681075	220.204	-2.612	8.079	0.000
AE_t	31	41.399	44.90000	59.30000	27.3	15.690	-1.688	5.220	0.000
CO_{2t}	31	91.901	91.79000	107.5700	68.05000	10.369	-0.408	2.275	0.463
$RGDP_t$	31	36247882	28957710	69023930	15263929	187	0.599	1.828	0.162
URB_t	31	51741306	46947855	94518555	23956989	2117	0.513	2.051	0.283

Sources: Author's Computation using EViews 9; Note: Prob. means Jarque-Bera P-Values.

Coming down to correlation analysis in **Table 2**, all the variables are in natural logarithm form. All the explanatory variables (i.e. AE_t, CO_{2t}, $RGDP_t$ and URB_t) have positive correlation with the explain variable (i.e. ED_t). This indicates that increase in access to electricity (AE_t), CO_{2t} emission (CO_2), real gross domestic products ($RGDP_t$) and urbanization (URB_t) are associated with increase in energy demand and vice versa. The highest approximated correlation value is between energy demand (ED_t) to real gross domestic product ($RGDP_t$) and the lowest correlation is between energy demand (ED_t) to CO_2 emission (CO_{2t}).

Table 2: Correlation coefficients of energy demand

Variables	**ln**ED_t	**ln**AE_t	**ln**CO_{2t}	**ln**$RGDP_t$	**ln**URB_t
$lnED_t$	1.000				
$lnEA_t$	0.761	1.000			
$lnCO_{2t}$	0.330	0.472	1.000		
$lnRGDP_t$	0.881	0.872	0.199	1.000	
$lnURB_t$	0.840	0.933	0.312	0.982	1.000

Sources: Authors Computation using EViews 9

To inspect the property of the data before estimating the long run equilibrium relationship, the following are required. At first, we check for the stationarity or integration properties of the data, by means of the widely used Augmented Dickey-Fuller (ADF) and Philip-Perron (PP) unit root tests, while breakpoint unit root test will serve as robustness check to ADF and PP results given that the variables are non-stationary. **Table 3a** reported the results of ADF and PP unit root tests. The results for ADF test revealed that ED_t and AE_t are stationary at level values and they are said to be integrated of order I(0) while CO_2, $RGDP_t$ and URB_t are stationary at first difference and they are said to be integrated of order I(1). But coming down to Philip-Perron (PP) unit root test also in **Table 3a** only AE is stationary at level and is said to be integrated of order I(0) whereas ED_t, CO_{2t}, $RGDP_t$ and URB_t are stationary at first difference and they are said to be integrated of order I(1). Therefore, since there is a mixture of order of integration in both ADF and PP unit root tests i.e. two variables are I (0) and three variables are I (1) in ADF, while in PP one variables is I(0) and four variables are I(1), then Autoregressive Distributed lag (ARDL) model is more efficient to be utilize as an analytical tool for this research work.

Table 3a: **Augmented Dickey Fuller Unit Root Test Result (ADF)**

	Level Values		First Difference		
Variables	**Constant**	**Constant & Trend**	**Constant**	**Constant & Trend**	**Order of Integration**
$lnED_t$	-1.340 (0.595)	-2.471 (0.338)	-4.485^a (0.001)	-4.382^a (0.009)	I (0)
$lnAE_t$	-2.727^c (0.084)	-6.064^a (0.000)	------------------	----------------	I (0)
$lnCO_{2t}$	-2.776^c (0.073)	-2.999 (0.148)	-5.855^a (0.000)	-5.723^a (0.000)	I (1)
$lnRGDP_t$	-0.376 (0.900)	-1.942 (0.607)	-2.694^c (0.087)	-2.624 (0.273)	I (1)
$lnURB_t$	0.794 (0.992)	-3.092 (0.126)	-2.631^c (0.098)	-2.593 (0.285)	I (1)

Philip Perron Unit Root Test Result (PP).

Variables	**Constant**	**Constant & Trend**	**Constant**	**Constant & Trend**	**Order of Integr.**
$lnED_t$	-1.392 (0.570)	-2.471 (0.338)	-4.422^a (0.001)	-4.300^b (0.011)	I (1)
$lnAE_t$	-3.365^b (0.021)	-6.257^a (0.000)	--------------	--------------	I (0)
$lnCO_{2t}$	-2.709^c (0.0842)	-2.973 (0.155)	-9.957^a (0.000)	-9.840^a (0.000)	I (1)
$lnRGDP_t$	-0.154 (0.934)	-1.540 (0.792)	-2.694^c (0.087)	-2.624 (0.273)	I (1)
$lnURB_t$	-0.257 (0.920)	-1.766 (0.695)	-2.647^c (0.095)	-2.593 (0.285)	I (1)

Sources: Authors computation using EViews 9; Note: Values in parentheses are the P-values and [a, b & c] represents statistically significant at 1%, 5% & 10% levels.

However, at times, ADF and PP tests may not produce dependable estimates if there is an existence of structural break in the series and as such they could generate a biased result. To stay away from such doubt, we have equally utilized breakpoint unit root test and the result is reported in **Table 3b.** The breakpoint unit root test result indicate that AE, CO_2, RGDP and URB are stationary at level values and they are said to be integrated of order I(0) while ED is stationary at first difference and is to be integrated of order I(1). In summary, the breakpoint unit root test result also indicates the combination of I(1) and I(0) variables. For this reason, the result of breakpoint unit root test too supports the application of Autoregressive Distributed Lag (ARDL) model.

Table 3b: Breakpoint unit root test result

	Level				First difference				
Variables	Constant	Break Point	Constant & trend	Break point	Constant	Break point	Constant & trend	Break point	I(d)
$lnED_t$	-3.003 (0)	2000	-3.747 (1)	2002	-5.068 (2)^a	2009	-4.973 (2)^b	2009	I(1)
$lnAE_t$	-3.003 (4)	2011	-7.710 (0)^a	2003	-8.796 (0)^a	2011	-6.093 (3)^a	2010	I(0)
$lnCO_{2t}$	-3.075 (0)	2015	-5.471 (0)^a	2005	-6.057(0)^a	1998	-6.055 (0)^a	2007	I(0)
$lnRGDP_t$	-5.478(0)^a	2001	-3.898 (6)	2009	-3.168 (0)	2002	-4.756 (0)^c	2001	I(0)
$lnURB_t$	-10.285(4)^a	2000	-5.036(6)^a	2001	-3.450(1)	2002	-11.921(4)^a	2000	I(0)

Source: Eviews 9; Note: $^{a, b \& c}$ stands for 1, 5 & 10% levels of significance and values in brackets are the lag lengths, while I(d) stands for the order of integration of the variables.

From the results of the unrestricted vector autoregression (VAR) is reported in **Table 4** below, using sequential modified LR test statistic, Final Prediction Error, Akaike Information Criterion (AIC), Schwarz criterion (SC) and Hannan-Quinn criteria (HQ) each test at 5% level of significance revealed that lag 2 should be selected. Therefore, in line with the Schwarz information criterion (SIC), lag 2 is the optimal lag length for this study.

Table 4: VAR lag order selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	162.5750	NA	7.71e-13	-13.70218	-13.45533	-13.64009
1	319.5234	232.0107	8.52e-18	-25.17595	-23.69487	-24.80346
2	380.9067	64.05208^k	5.18e-19^k	-28.33971^k	-25.62440^k	-27.65682^k

Sources: Authors computation using EViews 9. Note: k is the optimum lag selected by different lag selection criteria's

Having known the optimum lag length, the next step was to determine the cointegration relationship among the series by employing ARDL bounds test. The null hypothesis of no cointegration (H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$) was tested along with the alternative hypothesis of cointegration relationship (Ha: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq 0$). The product of this test depicted in **Table 5** revealed that the null hypothesis of no cointegration relationship among the series was rejected for the entire period under study (i.e. 1987 to 2017), at 1% level of significance. The estimated F-statistics value of 5.297 exceeded the lower bound critical value of 3.74 and the upper bound critical of value of 5.06 at the aforementioned level of significance. As such, existence of cointegration relationship is confirmed in this respect. Meaning that, the series are moving together or that they split an ordinary connection in the long run. This product supported by the work of researchers such as Saqlain et al. (2013), Hassan (2018), Kouton and Amonle (2019) and Musa et al. (2019).

Table 5 Bounds Test Result

			Bound test critical values [Unrestricted intercept &no trend]		
Model	**F-stat.**	**Lag**	**Level of significance**	**I (0)**	**I (1)**
1987 to 2017	5.297	1	1%	3.74	5.06
F($lnED_t$ /$lnCO_{2t}$,$lnRGDP_t$,$lnURB_t$,$lnAE_t$,)			5%	2.86	4.01
K = 4 & n = 30			10%	2.45	3.52

Sources: Author's computation using EViews 9.

The Johansen Juselius test for cointegration relationship using representation with Trace statistic and representation with Max-Eigen value statistic as reported in **Table 6** below revealed the existence of 3 cointegration equations in the trace statistic representation and 4 cointegration equations in the max-eigen statistic representation. Therefore, we bring to a conclusion that there is a cointegration relationship among explain variable and explanatory variables and that all the variables moved jointly in the long run. The Johansen Juselius test for cointegration result corroborates the bounds test result of ARDL.

Table 6: Johansen Juselius Test for Co-integration

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Max-Eigen Statistic	0.05 Critical Value
C = 0	0.949	140.362^a (0.000)	69.818	68.602^a (0.000)	33.876
C ≤ 1	0.721	71.760^a (0.000)	47.856	29.360^a (0.000)	27.584
C ≤ 2	0.691	29.797^a (0.001)	29.797	27.085^a (0.006)	21.131
C ≤ 3	0.466	15.313 (0.053)	15.494	14.446^b (0.046)	14.264
C ≤ 4	0.036	0.866 (0.352)	3.841	0.866 (0.352)	3.841

Sources: Authors computation using EViews 9; Note: Values in parentheses are the P-values and $^{a\ \&\ b}$ represent statistically significant at 1% & 5% levels of significance.

Following the establishment of cointegration relationship among the variables, the long run and short run models in equation 5 and equation 6 were estimated to get these long run and short run coefficients as reported in **Table 7** below. The results revealed that CO_2 emission is positive and significant at 1% level of significance. Meaning that 1% increase in CO_2 emission is associated with 0.242% increase in energy demand in the long run period.

Real gross domestic product is also positive and significant in explaining changes in energy demand. Specifically, 1% increase in RGDP is associated with 0.386% increase in energy demand in the long run period and this corroborates the findings of Hassan (2018). Urbanization is negative and significant in explaining changes in energy demand in the long run period. Precisely 1% changes in URB is associated with 0.378% decrease in energy demand in Nigeria. This supported the findings of Hassan (2018) and contradicts the findings of Chidinma et al. (2018).

Coming down to the short run outcome also reported in the **Table 7**, the results indicates that CO_2 emission and RGDP are positive while URB is negative and significant at 1% level of significance in explaining changes in energy demand. Meaning that 1% increase in CO_2 emission and RGDP are associated with 0.182% and 0.290% increase in energy demand in the short run period. While 1% increase in URB is associated with -0.346% decrease in energy demand in the short run and this finding corroborates the result of Hassan (2018) and this is contrary to the result of Chidinma et al. (2018). The error correction value of -0.37 satisfied the econometrics requirements of negative value, less than one and significant which means that the feedback or convergence rate to long run equilibrium is 37%. Precisely, the error correction term value also indicates that the long-run deviation from the energy demand is corrected by 37% every year.

The R-square value of 0.922 signifies that 92% variation in energy demand can be jointly explained by the explanatory variables and only 8% variation in energy demand is explained by the error term. The Durbin Watson value of 1.336 implies that the model is not free from first order serial correlation as the value is not within the range of 1.50 to 2.50. The F-statistic which is the test for the overall significant of the model indicates the value of 45.084 which is highly significant at 1% level of significance. Meaning that the all the explanatory variables in the model are jointly significant in explaining the changes in energy demand. The error correction value of -0.751 satisfied the econometrics requirements of negative, less than one in value and significant which means that the feedback or convergence rate to long run equilibrium is 75%. The error term value indicates that for every short run disequilibrium, about 75% of the disequilibrium is corrected each year.

Table 7: Long run and Short run coefficients for ARDL (1, 0, 0, 0, 0) using Schwarz criterion (SIC)

Dependent Variable = $\ln ED_t$				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
$\ln CO_{2t}$	0.242	0.071	3.414[a]	0.002
$\ln RGDP_t$	0.386	0.075	5.134[a]	0.000
$\ln URB_t$	-0.461	0.124	-3.701[a]	0.001
$\ln AE_t$	0.098	0.082	1.183	0.251
C	6.595	0.735	8.967[a]	0.000
Dependent Variable = $\Delta \ln ED$				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
$\Delta \ln CO_{2t}$	0.182	0.040	4.472[a]	0.000
$\Delta \ln RGDP_t$	0.290	0.063	4.588[a]	0.000
$\Delta \ln URB_t$	-0.346	0.097	-3.539[a]	0.002
$\Delta \ln AE_t$	0.073	0.065	1.122	0.275
ECM (-1)	-0.751	0.150	-5.010[a]	0.000

$ecm = \ln ED_t - 0.242 \times \ln CO2_t - 0.387 \times \ln RGDP_t + 0.461 \times \ln URB_t - 0.098 \times \ln AE - 6.595$

R^2: 0.922, Adjusted R-squared : 0.901, DW-statistic: 1.336, F-stat: 45.084[a] (0.000), Schwarz criterion: -5.174, Akaike info criterion: -5.466

Sources: Authors computation using EViews 9; Note. ECM = Error Correction Model. [a & b] and are significant at 1% & 5% levels of significance.

To guarantee the reliability of the estimated coefficients, the reliability tests of serial correlation using Breusch-Godfrey serial correlation LM test, functional form using Ramsey RESET test, normality test using Jarque-Berra and the heteroskedasticity using Autoregressive conditional heteroscedasticity (ARCH) were engaged and the outcome is reported in **Table 8** below. The outcome showed that the null hypotheses for the serial correlation LM test, normality test and heteroskedasticity test could not be rejected for the model. This shows that the model reliable for policy making and statistical inferences.

Table 8 Residuals of the Autoregressive Distributed Lag Diagnostic Tests.

Test statistics	**LM version**	**F-version**
Serial correlation	CHQ (2) = 3.334 [0.188]	F(2,17) = 1.308 [0.296]
Heteroscedascity	CHQ (5) = 3.342 [0.647]	F(2,24) = 0.586 [0.710]
Functional form	Not applicable	F(1, 18) = 0.128 [0.724]
Normality	JB = 0.018 [0.600]	Not applicable
CUSUM	Stable	
CUSUMSQ	Stable	

Sources: Authors computation using EViews 9; Note. The values in [ ] are the probability values. LM = langrange multiplier test, CHQ = chi-square.

In determining the stability of the estimated coefficients of energy demand equation for Nigeria, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests as suggested by Pesaran and Pesaran (1997) were utilized.

From the figure 1 and 2 of CUSUM and CUSUMSQ, it can be noticed that both the CUSUM and CUSUMSQ plots do not pass through the 5% critical boundaries, indicating that over the entire sample period of 1987 to 2017, there is an existence of stability among the estimated coefficients. Therefore, the estimated coefficients are reliable and suitable for policy making in Nigeria.

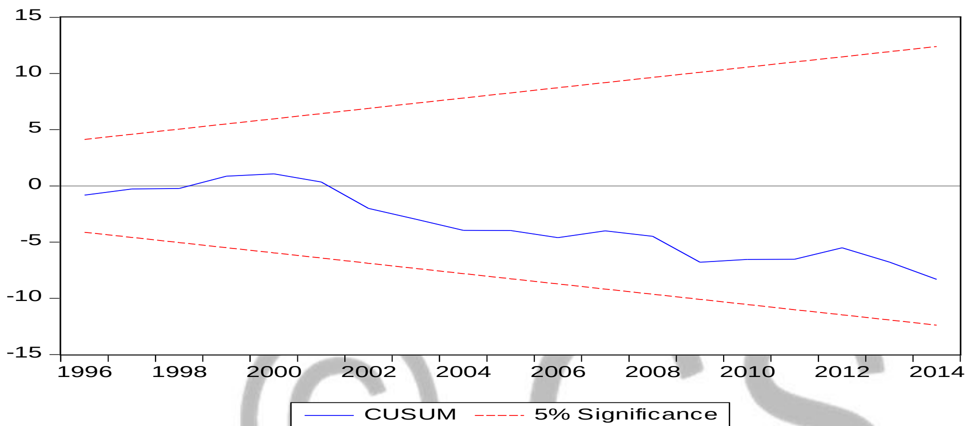

Figure 1: Stability test for assessing the key drivers of energy demand in Nigeria

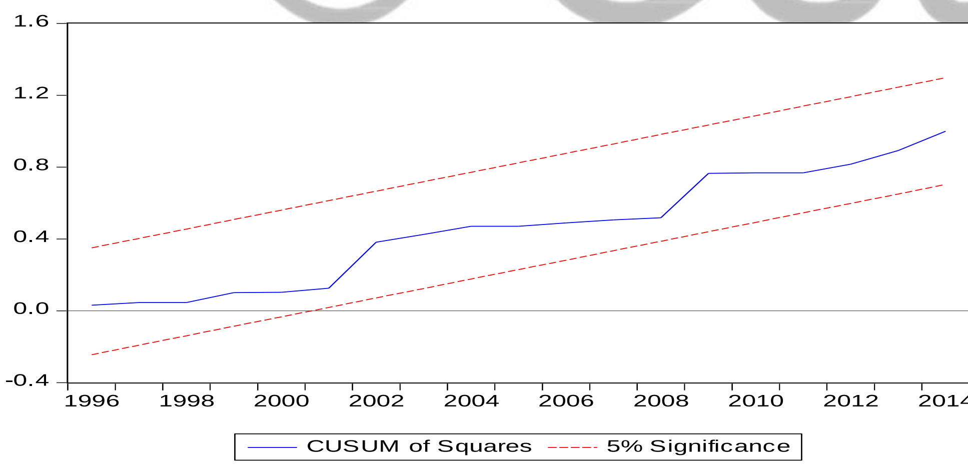

Figure 2 Stability test for assessing the key drivers of energy demand in Nigeria

As strength checks to the ARDL results, we have employed dynamic OLS, fully modified OLS and Canonical CR, and their coefficients are reported in **Table 9**. The outcome demonstrate that in all the three estimators CO_2 emission and real GDP have are positive and significance whereas urbanization is negative and also significant in influencing changes in energy demand in the long run in Nigeria. However access to electricity appears to be negative and insignificant in explaining changes in energy demand in accordance with the DOLS, FMOLS and CCR results. These findings corroborate the long run ARDL estimates depicted in **Table 7** above.

Table 9 Estimated results for the assessment of key drivers of energy demand using time Series DOLS, FMOL and CCR.

Dependent Variable = $\ln ED$:	DOLS		FMOLS		CCR	
Regressors	**Coefficients**	**SE**	**Coefficients**	**SE**	**Coefficients**	**SE**
CO_2 Emission	0.193^b		0.179^a		0.178^a	
	(2.783)	0.069	(3.848)	0.046	(3.396)	0.052
Real GDP	0.455^b		0.338^a		0.335^a	
	(2.724)	0.167	(5.674)	0.059	(5.578)	0.060
Access to Electricity	0.506		0.089		0.092	
	(1.789)	0.283	0.981)	0.091	(1.025)	0.090
Urbanization	-0.722^c		-0.389^a		-0.386^a	
	(-2.365)	0.305	(-3.733)	0.104	(-3.461)	0.111
Constant	8.474^b		6.474^a		6.467^a	
	(4.360)	1.943	(9.798)	0.660	(8.466)	0.763
R^2	0.975		0.906		0.975	
Adjusted R^2	0.911		0.886		0.911	
Normality test:	0.898 [0.638]		0.390 [0.822]		0.893 [0.637]	

Sources: Authors computation using EViews 9; Note. Numbers in brackets are the t-statistics and Numbers in [ ] are the P-Values. DV = Dependent variable, DOLS = dynamic ordinary least squares; FMOLS = fully modify ordinary least square; OLS = Ordinary Least Square; SE = standard error. [a, b] & [c] indicates significant at 1%, 5% & 10% levels of significance respectively.

After checking the strength of ARDL long run coefficients, then causal link between the variables was checked using VECM granger causality test in a vector autoregressive (VAR) system. The existence of long run relationship as represented in **Table 5** and **Table 6** above suggest the existence of causal relation in at least one direction. The estimated short run and long run causality results are offered in **Table 10** and the summary of causality results is given in **Table 11**. The long run causality results reveal that ECT_{t-1} in access to electricity equation has fulfilled all the econometrics requirements of negative, less than one in value and statistically significant. This suggests that there is a long run causality running from urbanization, real GDP, CO_2 emission and energy demand to access to electricity. In equation with CO_2 emission as dependent variable, the ECT_{t-1} value is also negative, less than one in value and statistically significant. Therefore we conclude that there is long run causality running from urbanization, real GDP, CO_2 emission and energy demand to CO_2 emission.

Apart from the long run causality, the short run causality was also reported in **Table 10**. However, in the short run, there is bidirectional causality from running from real GDP to energy demand and urbanization to real GDP. There is also unidirectional causality running from CO_2 emission to real GDP and from access to electricity to real GDP. The rest of the interpretations with regards to the long run and short run causality results are offered in **Table 11** below.

The VECM reliability tests results are reported in the lower part of **Table 10** which indicates that the model is steady and reliable as all the null hypotheses of the tests were accepted, and therefore its coefficients are acceptable for statistical reasoning.

Table 10 Vector error correction model granger causality test result

	Direction of Causality					
	Short run					**Long run**
Dependent Variables	$\sum \Delta \ln ED_t$	$\sum \Delta \ln AE_t$	$\sum \Delta \ln CO_{2t}$	$\sum \Delta \ln RGDP_t$	$\sum \Delta \ln URB_t$	ECT_{t-1}
$\Delta \ln ED_t$	----	1.148 (0.283)	0.001 (0.972)	4.022^b (0.044)	1.664 (0.197)	0.061 (0.797)
$\Delta \ln AE_t$	0.268 (0.604)	----	0.197 (0.657)	1.003(0.316)	0.7409 (0.389)	-0.922^b (0.049)
$\Delta \ln CO_{2t}$	0.069 (0.791)	0.557 (0.455)	----	1.307 (0.252)	2.001 (0.157)	-0.177^b (0.020)
$\Delta \ln RGDP_t$	4.793^b (0.028)	5.930^b (0.014)	5.428^b (0.019)	----	11.398^a (0.000)	0.583 (0.776)
$\Delta \ln URB_t$	0.633 (0.425)	0.244 (0.620)	1.382 (0.239)	3.396^c (0.065)	----	0.024 (0.099)

Diagnostic tests: Akaike information criteria = -26.524, Schwarz criterion: -24.549, VEC residual serial correlation LM test = 29.985 (0.224), VEC White heteroscedasticity test = 180.816 (0.468), VEC Jarque Bera normality test = 0.093 (0.954)

Sources: Authors computation using EViews 9; Note. Values in parentheses are the P- values. LM = langrange multiplier; VEC = vector error correction $^{a,\ b\ \&\ c}$ indicates significant at 5% level.

Table 11 Summary of VECM granger causality test results

Direction of causality	**Short run (F-statistics)**	**Long run (ECT_{t-1})**
$\ln EA_t$ causes $\ln ED_t$	NO	NO
$\ln CO_{2t}$ causes $\ln ED_t$	NO	NO
$\ln RGDP_t$ causes $\ln ED_t$	At 5% level of significance	NO
$\ln URB_t$ causes $\ln ED_t$	NO	NO
$\ln ED_t$ causes $\ln EA_t$	NO	At 5% level of significance
$\ln CO_{2t}$ causes $\ln EA_t$	NO	At 5% level of significance
$\ln RGDP_t$ causes $\ln EA_t$	NO	At 5% level of significance
$\ln URB_t$ causes $\ln EA_t$	NO	At 5% level of significance
$\ln ED_t$ causes $\ln CO_{2t}$	NO	At 5% level of significance
$\ln EA_t$ causes $\ln CO_{2t}$	NO	At 5% level of significance
$\ln RGDP_t$ causes $\ln CO_{2t}$	NO	At 5% level of significance
$\ln URB_t$ causes $\ln CO_{2t}$	NO	At 5% level of significance
$\ln ED_t$ causes $\ln RGDP_t$	At 5% level of significance	NO
$\ln EA_t$ causes $\ln RGDP_t$	At 5% level of significance	NO
$\ln CO_{2t}$ causes $\ln RGDP_t$	At 5% level of significance	NO
$\ln URB_t$ causes $\ln RGDP_t$	At 1% level of significance	NO

$\ln ED_t$ causes $\ln URB_t$	NO	NO
$\ln EA_t$ causes $\ln URB_t$	NO	NO
$\ln CO_{2t}$ causes $\ln URB_t$	NO	NO
$\ln RGDP_t$ causes $\ln URB_t$	At 10% level of significance	NO

Source: Authors computation using EViews 9.

5.0 Summary and Conclusion

The study utilized of ARDL approach to cointegration relationship to assess the determinants of energy demand in Nigeria. The assessment was done for the sample period of 1987 to 2017. The direction of causality was tested by employing VECM granger causality in both the short run and the long run periods. Firstly, the study tested for the existence of long run equilibrium relationship after determining the optimum lag and found that they variables were cointegrated. Following the cointegrated series, the long run and short run models were estimated and the results revealed that CO_2 emission and real gross domestic product are responsible for increase in energy demand within the study period while urbanization is found to be negative in both the two periods. Access to electricity appeared to be insignificant in explaining the changes in energy demand in both the long run and short run periods. The diagnostic checks were performed on the model and the results indicate that the model is good fit and have fulfilled nearly all the requirements for classical linear regression.

The checking for robustness was done using DOLS, FMOLS and CCR, and their outcomes corroborates the results of ARDL long run model. The VECM granger causality was applied to test the direction of causality, which indicated significant long run causality in the in access to electricity and CO_2 emission equations. In the short run period, there is bidirectional causality running from RGDP to ED and URB to RGDP together with unidirectional causality running from CO_2 to RGDP and from AE to RGDP respectively.

The main conclusion drawn from this research work is that since CO_2 emission, urbanization and real GDP are significance in explaining changes in energy demand in both long run and short run periods in Nigeria over the study period of 1987 to 2017, then these variables are said to be the key drivers of energy demand in Nigeria and policy measures with regards to energy demand in the country should be inform of long run and short run periods.

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