SSRG International Journal of Economics and Management Studies
ISSN: 2393–9125 / https://doi:10.14445/23939125/IJEMS-V10I10P105

Volume 10 Issue 10, 35-46, October 2023

Original Article

Electricity Consumption and Economic Growth in Nigeria: A Causality Analysis using ARDL Approach

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Received: 09 August 2023 Revised: 26 September 2023 Accepted: 08 October 2023 Published: 26 October 2023

Abstract - *This study examines the causality relationship between electricity consumption and economic growth in Nigeria using time-series data between 1990 and 2020. The Autoregressive Distributed Lag (ARDL) model was used as the analytical technique, with electricity consumption and Gross Domestic Product (GDP) as the independent and dependent variables, respectively. The research uses secondary data with various validation tests. The outcome of the cointegration test revealed the existence of a long-run relationship between the variables. Electricity consumption by the commercial sector has a short-term negative and insignificant effect on GDP. Consumption by the industrial sector had a positive and significant correlation with GDP both in the short and long term. Residential consumption had a long-term, significant positive correlation with GDP. The outcome of this study underscores the need for the Nigerian government to implement strategic reforms to promote investments in the electricity sector to help boost consumption and contribute to economic development in the country.*

Keywords *- ARDL, Causality, Electricity, GDP, Macroeconomic indices.*

1. Introduction

Energy consumption is a key ingredient that drives economic growth in a society. The consumption of electricity by the various economic agents in a country, such as residential, industrial, and commercial sectors, enhances the quality of life in the country. It is a key enabler and a vital component of infrastructural development and industrialization. Nigeria occupies a unique position as Africa's largest economy and the country with the largest population on the continent. In addition, the country is blessed with an abundance of primary energy sources, the most significant of which are crude oil and natural gas, a key resource for electricity generation. Despite Nigeria's substantial natural gas reserves, the country faces persistent challenges in delivering consistent and reliable electricity to its citizens, adversely affecting its economy.

The erratic power supply has resulted in low productivity and poor quality of goods and services and hence contributed to an increase in poverty. The shortfall in meeting electricity demand is one of the primary causes of the country's underdevelopment. Some of the key factors that have led to the unreliable supply of electricity in the country can be linked to capacity constraints, aging infrastructures, low investments in the sector, and theft and destruction of electricity infrastructures. The interplay between electricity consumption by the country's different economic agents and its impact on the national economy can easily be represented by a simple flowchart, as depicted in Fig 1 below.

Across most of sub-Sahara Africa, a historical trend of energy poverty has lasted many decades. For instance, about 80% of the electricity budget in Sub-Saharan Africa (excluding South Africa) is spent on fueling backup generators. This is in large part due to chronic underfunding in the power sector. About $350 billion in additional investment is required to help increase the supply and transmission of electricity across Sub-Saharan Africa [11]. However, in the last 15 years, electricity consumption in Sub-Saharan Africa has doubled, and it is expected to increase further by about eight times by 2050. This is not exactly the case with Nigeria, where only marginal increases in generation capacity and consumption have been recorded within the same period. Nigeria's position in the 2020 Doing Business report is 171st out of 190 countries, primarily due to challenges with the availability of electricity, which hinders the private sector. Nigeria has a population exceeding 200 million and possesses a total of 4 hydroelectric and 23 thermal power stations, resulting in a combined electricity generation capacity of approximately a paltry 14,000 MW. Apart from some of the thermal power stations which were established in the last 2 decades, most of the first-generation hydro and thermal power stations in the country were established between four and five decades ago. With a relatively poor maintenance culture, these stations are replete with aged infrastructure, and their performances are largely inefficient. Undoubtedly, the electricity supply shortage has had significant negative impacts on all facets of the Nigerian economy. One such area where the impact has been quite significant is in the commerce and industries sector. From small and medium-scale enterprises to major industrial establishments, interruptions in public power supply mean reduced productivity and higher costs of goods and services. One consequence is an increasing closure rate of existing businesses and a higher mortality rate for start-ups. In two separate studies conducted by [24] and [13], looking at the impact of power cuts on the mortality rate for new businesses across a select number of countries in Africa, the conclusion is that Nigeria has one of the lowest new business (start-up) density rates amongst the countries covered in the study, as shown in Figure 2. The study concludes that the tendency for new businesses to fail within a fixed period because of frequent power outages is higher in Nigeria than in most African countries.

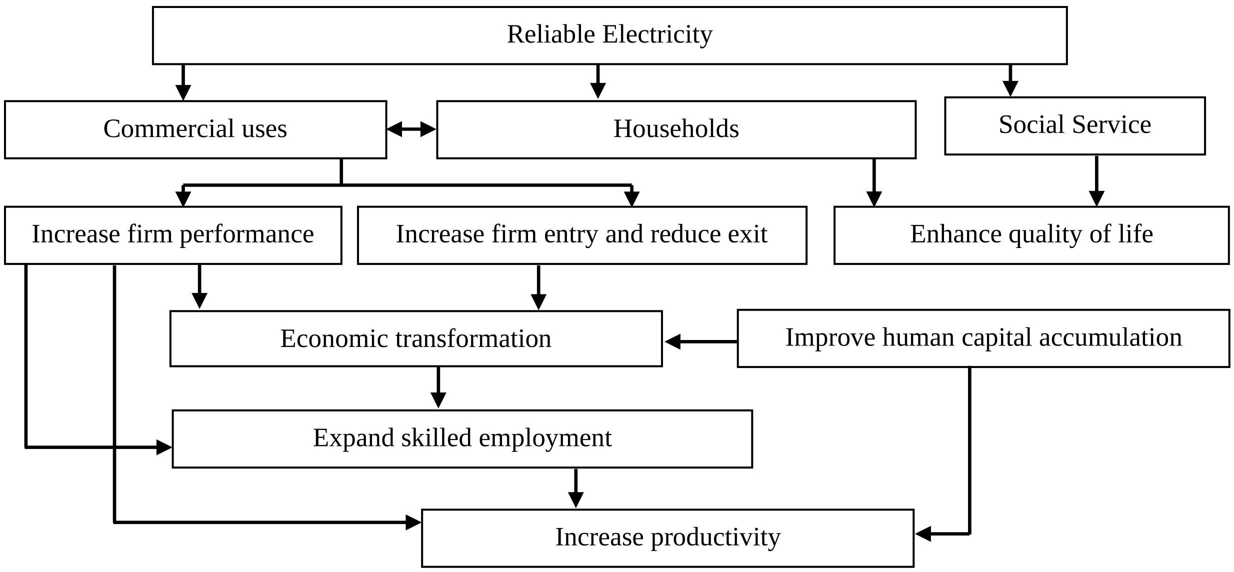


Fig. 1 Impact of electricity dependability on economic change

Source: [12]

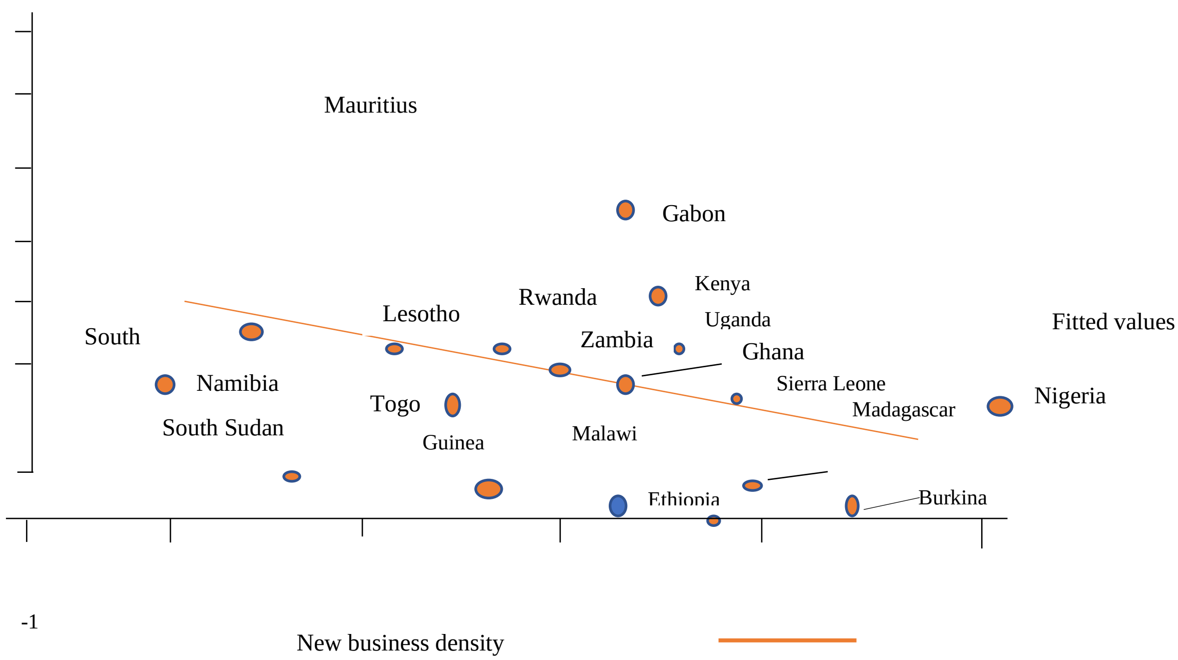


Fig. 2 A plot of power outage and firm entry density

Source: [24] and [13].

In the past, the Federal Government of Nigeria had made some bold attempts at implementing reforms in the electricity sector. In 2014, Nigeria's state-owned utility company, the Power Holding Company of Nigeria (PHCN), went through reforms that involved dividing its entities into smaller units and privatising them to enhance their operational efficiencies. The privatisation process encompassed selling off a total of 12 power plants owned by PHCN, consisting of 8 thermal plants and 4 hydroelectric plants. The objective was to attract private sector investments into the electricity sector and to improve the efficiency of the nation's electricity distribution system. Presently, there is an urgent need to build more power stations across the country, increase the load-bearing capacity of the transmission network, and expand infrastructure in the distribution network, including providing coverage in some under-served rural areas. These goals were mostly unmet nearly a decade after the reform program due to substantial program flaws and business climate issues. In addition, it is imperative for Nigeria to implement policy reforms that can attract investments in green energy technologies as part of the ongoing energy transition to low low-carbon economy, ultimately leading to increased installed capacity and electricity consumption.

As stated earlier, while possessing ample energy resources, Nigeria has had only modest advancements in power consumption throughout the preceding 15-year period, in contrast to the rise shown in the Sub-Saharan African region. The observed discrepancy implies distinct obstacles within Nigeria's energy industry that impede its development compared to other African nations. The comprehension of the factors contributing to Nigeria's relatively slow rise in power consumption is of utmost importance, as it provides valuable insights for formulating efficient policies and strategies to tackle energy-related issues and foster sustainable economic progress.

There is a causative interplay that exists between energy consumption and economic development, and for a long time, this has been an area of interest for many scholars. There are two main issues to consider when analysing the connection between energy consumption and economic growth indices, measured primarily by GDP growth rate. The first one is the availability of affordable and reliable electricity (energy) and how that helps drive economic activities. The growth of an economy will be sub-optimal, with insufficient energy availability. Secondly, specific economic development conditions determine the extent and breadth of energy openness and usage. Growth in the economy can lead to or attract more investments in the use of energy resources. In Nigeria, some researchers have made use of a wide variety of statistical measurement techniques to investigate time-series data, looking for patterns in how much energy the country consumes in connection to its gross domestic product (GDP) development. This has sometimes involved expanding the Cobb–Douglas production function by including energy as a new variable. Using distinct schedules and/or approaches has resulted in somewhat divergent outcomes about Nigeria's cointegration relationship between power consumption and economic growth indices. [4] established an empirical research model, and the findings using the cointegration technique led to the conclusion that the growth in the Nigerian economy is correlated with the country's energy consumption, excluding coal usage. Similar works, with somewhat slightly divergent outcomes, were presented in the studies carried out by [6], [21], [1], [5], and [22] also examined the link between energy use and industrial development. Empirical analyses were conducted in these research works to evaluate the causal link between energy use and GDP growth. Different models were used for these purposes, including the ordinary least squares (OLS) method, the Johansen cointegration model, and the Granger causality model. Various models, including the non-Granger causality test, the Vector Error Correction Model (VECM), and the research-based explanatory technique, have been used in similar investigations carried out [2], [15], and [18]. The factors responsible for the slight differences in the findings from the various studies include differences in methodologies employed, biases in data selection, and problems with data quality or model definition. It is worth noting that most of these works approached the connection between GDP growth and energy usage through feedback techniques. Since the Nigerian economy has witnessed more annual growth than contraction over the years, despite the country's current state of higher-than-average energy poverty, the country may be an exception; here, it is worth pointing out that the country's energy demand does not match rising economic activity. However, through empirical data, it is important to use evidence from the real world to have a good grasp of how an increase in electricity consumption, or the use of energy in general, is linked to a flourishing economy and its role in that process.

This study aims to investigate the causal relationship between electricity consumption and economic growth in Nigeria. This study employs the Autoregressive Distributed Lag (ARDL) model to examine the long-term relationship between electricity consumption and Economic growth in Nigeria, distinguishing it from previous studies that have been reviewed. The ARDL model is appropriate for small sample sizes, as well as for both stationary and non-stationary data, encompassing both endogenous and exogenous variables. This study utilises data on electricity consumption by different economic agents (commercial sector, household consumption, and industrial sector) as independent variables, with Gross Domestic Product (GDP) growth rate serving as the dependent variable.

2. Materials and Methods

The study comprises three fundamental stages: data collection, data analysis using a model, and interpretation of findings. A correlation test is conducted to examine the potential causal relationship between electricity consumption and economic growth indices using the available data.

2.1. Data Source

This research makes use of secondary data obtained from the World Bank and the Nigerian National Bureau of Statistics. The study was conducted with the use of the Eviews 10.0 software tool.

2.2. Model Specification

This research employs the ARDL model to conduct an empirical analysis on a time series dataset of quarterly public power consumption and economic growth (GDP) in Nigeria. The dataset spans a period of 30 years. The current study presents an investigation of the link between energy consumption patterns and economic growth indicators in both the short-run and long-run, based on the modelling exercise. The electricity consumption by the different economic agents in the country is expressed in kilowatt-hours per person (households) and kWh per unit output (industrial users). The real GDP is a measure of the value of goods and services that a country produces annually after adjusting for inflation and is expressed in percentages.

The model incorporates the past values of both the dependent variables and the regressors, as well as the present and past values of the regressors, as explanatory variables. An ARDL model typically has both endogenous and exogenous factors. The ARDL (m, n) model is often formulated in the following manner:

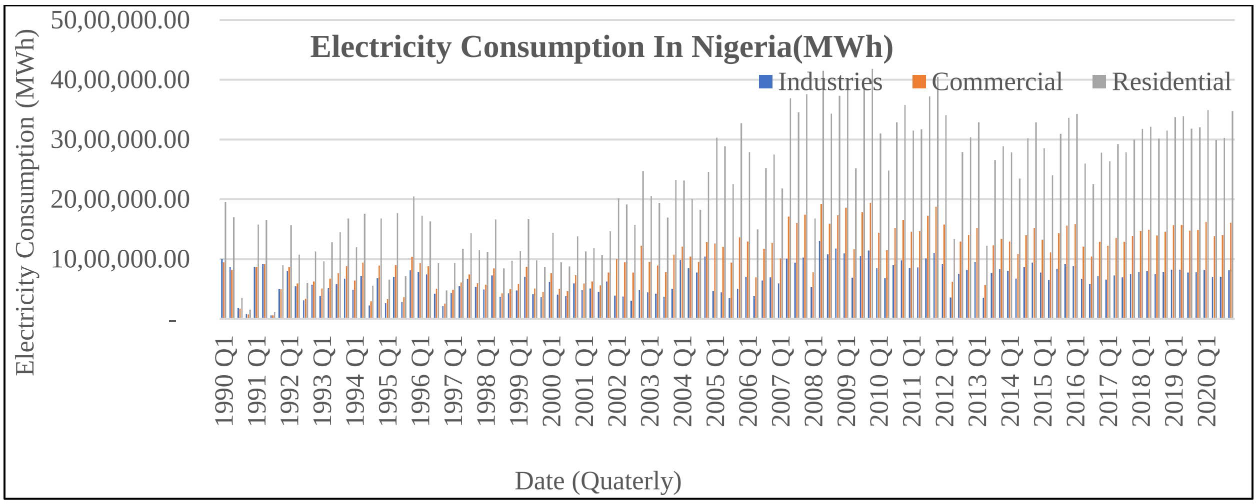


Fig. 3 Electricity consumption by different economic agents in Nigeria.

Source: Author's compilation

$$\Delta \ln Y_t = a_1 + \sum_{i=1}^{m} a_{11} \Delta LY_{t-i} + \sum_{i=0}^{n} a_{22} \Delta X_{t-i} + n_1 ECT_{t-1} + \mu_{1i} \quad (1)$$

$$\Delta \ln X_t = a_1 + \sum_{i=1}^{m} a_{21} \Delta LX_{t-i} + \sum_{i=0}^{n} a_{22} \Delta Y_{t-i} + n_2 ECT_{t-1} + \mu_{2i} \quad (2)$$

In the given context, the variable t denotes the time in years. The disturbance term is represented by µi. The optimal lag order, denoted by m, is related with the dependent variable and is measured in years. Similarly, the optimal lag order, denoted by n, is linked with the independent variable and measured in years.

The relationship between the dependent and independent variables may be succinctly represented in a dependency equation, as seen below:

$$GDP = f(CEC, IEC, REC) \quad (3)$$

Where GDP represents the GDP growth rate, CEC is electricity consumption by the commercial sector, IEC is electricity consumption by the industrial sector, and REC is electricity consumption by residents or households. By combining the functional relationship between the dependent and independent variable (the dependency equation) and expressing it in a general ARDL model gives the following equations:

$$GDP_t = a_{og} + a_{1g} CEC + a_{2g} IEC + a_{3g} REC + \varepsilon_{tg} \quad (4)$$

The variables in the above equation (4) can be converted into a natural log, resulting in the equation below:

$$In\ GDP_t = a_{og} + a_{1g} In\ CEC + a_{2g} In\ IEC + a_{3g} In\ REC + \varepsilon_{tg} \quad (5)$$

Expressing the macro-economic indices dependency equations in the ARDL cointegration form:

$$\Delta \ln GDP_t = a_{og} + \sum_{i=1}^{n} \alpha_{1g} \Delta \ln GDP_{t-i} + \sum_{i=1}^{n} \alpha_{2g} \Delta \ln CEC_{t-i} + \sum_{i=1}^{n} \alpha_{3g} \Delta \ln IEC_{t-i} + \sum_{i=1}^{n} \alpha_{4g} \Delta \ln REC_{t-i} + \gamma_{1g} \ln GDP_{t-1} + \gamma_{2g} \ln CEC_{t-1} + \gamma_{3g} \ln IEC_{t-1} + \gamma_{4g} \ln REC_{t-1} + \varepsilon_{tu} \quad (6)$$

Where $\epsilon_{t(i,\ j,\ u,\ and\ g)}$ is the white noise error term for all the dependency models, Δ is the first difference, $\alpha_{0(i,\ j,\ u\ and\ g)}$ is the drift component for the dependent variables. The study uses the Akaike information criterion (AIC) to determine the lag length.

The study first checks for the existence of the long-run relationship between the variables, after which it tests for a short-run relationship using the Error Correction Model (ECM). The error correction model equation is shown below:

$$\Delta \ln GDP_t = a_{og} + \sum_{i=1}^{n} \alpha_{1g} \Delta \ln GDP_{t-i} + \sum_{i=1}^{n} \alpha_{2g} \Delta \ln CEC_{t-i} + \sum_{i=1}^{n} \alpha_{3g} \Delta \ln IEC_{t-i} + \sum_{i=1}^{n} \alpha_{4g} \Delta \ln REC_{t-i} + \emptyset i ECM_{t-1} + \varepsilon_{tu} \quad (7)$$

Where Δ is the first difference $\emptyset$ and is the error correction model coefficient. The error correction model (ECM) represents the adjustment rate for the long-run equilibrium following a shock.

2.3. Modeling Technique

[25] introduced the autoregressive distributed lag (ARDL) modelling technique, also called the Bounds test. The ARDL modeling technique is flexible, adaptable, and appealing because it can consider different lags in a wide range of variables. It can hold sufficient delays, and this helps achieve the best possible capture of the process of data generation. Thus, the ARDL model is applicable irrespective of the nature of the time-series data. For instance, it could be integrated fractionally, stationary at initial differences I(0), or stationary at levels [26]. The Pesaran critical values and the F-statistics are invalidated by this integration order, so the series should not be I(1) according to the ARDL framework. Time series that are either I(0) or I(1), or a combination of both, have had their values determined. Additionally, regardless of how endogenous the specific regressors are, accurate t-statistics and unbiased estimates can be obtained from an ARDL model. Because the proper lag selection eliminates residual correlation, the endogeneity problem is also addressed. It is possible to combine both the long-run equilibrium and the short-run corrections during the error correction process (ECM). A linear translation is used to achieve this without sacrificing long-term perspective knowledge. The approach allows for the correction of outliers using impulse dummies, and this methodology helps to differentiate between the two variables [20]. Finally, the ARDL framework only necessitates one form of equation, unlike other procedures that require a system of equations, and its interpretation and execution are very simple. ARDL employs the Ordinary Least Square (OLS) approach to cointegrate variables. For a small data sample, it is suitable for computing both the long-run and short-run elasticities. The above reasons dictate the use of the ARDL technique in this study.

A bouquet of validation tests was carried out on the data to verify and authenticate the data before it was used. Real GDP rate, inflation rate, and unemployment rate are a few examples of economic and financial time series data that frequently exhibit common patterns in their central (mean) and dispersed (variance, covariance) measures. To ensure that the results of a regression model and causality tests are reliable, the data must be transformed by testing for stationarity. De-trending is very necessary for time-series data that has a trending effect, and this can be done by either first differencing or performing time-trend regression. Based on the first differencing, a de-trending analysis was performed in this study.

This study uses the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), Elliott-Rothenberg-Stock Dickey Fuller-Generalized Least Squares (DF-GLS), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests to examine unit roots in time-series data. A Cumulative Sum (CUSUM) test was also conducted to determine if regression coefficients change consistently or suddenly. The CUSUM graph falls within the 5% significance line for the Null Hypothesis criteria (H_0) and exceeds the 5% significance line for the alternate Hypothesis criteria (H_1). Performing a cointegration test on the data is most appropriate for this study because it helps to model the time series while preserving their long-run information. [17] and [14], who provided tests and estimate procedures to ascertain whether a group of variables had a long-term relationship with one another within a framework of dynamic specification, first formalized the concept of cointegration. The cointegration test is a method used to verify the connection between time series data, preventing them from drifting too far apart. It involves a mix of stationary variables that are non-stationary and integrated to an order of magnitude. This test is crucial in econometric modelling, as it simulates a long-run equilibrium between time series that converge during a certain duration. Cointegration strengthens the statistical foundation of empirical error correction models by combining short- and long-term information in modelling variables. If the cointegration between the underlying variables cannot be established, it is imperative to continue working with variables with differences. The unrestricted error correction models mentioned below are the primary models in the ARDL bounds test framework.

$$\Delta LY_t = a_o + a_1 t + \sum_{i=1}^{m} \alpha_{2i} \Delta LY_{t-i} + \sum_{i=0}^{n} \alpha_{3i} \Delta LY_{t-i} + a_4 LY_{t-1} + a_5 LX_{t-1} + \mu_{1t} \quad (8)$$

$$\Delta LX_t = \beta_o + \beta_1 t + \sum_{i=1}^{m} \beta_{2i} \Delta LY_{t-i} + \sum_{i=0}^{n} \beta_{3i} \Delta LY_{t-i} + \beta_4 LY_{t-1} + \beta_5 LX_{t-1} + \mu_{2t} \quad (9)$$

The drift components are a_0 and β_0; the white noise components are μ_1t and μ_2t. Before deciding on the variables and other components, one can typically choose their preferred framework, like the Kuznets curve hypothesis, a production function strategy, a demand function strategy, or another. To enhance the predictability of a projected relationship, additional deterministic factors are gradually incorporated. Equations (8) and (9) demonstrate that each variable is dependent on its own previous values as well as the past values of other variable(s). Equations (8) and (9) are often used to represent the intercept and/or trend in ARDL models. Two models can be created, one with a trend and one without. In the initial stage of ARDL estimation, a total of (p + 1)k regressions are conducted to determine the optimal lag length for each variable. Here, p denotes the maximum number of lags, and k represents the number of variables present in the equation. Only one variable, Xt, is applicable in this example. The ARDL bounds cointegration test is conducted using the equations (8) and (9) framework. OLS is commonly employed for estimating these equations.

Checking if the assumptions of the regression analysis are met is achieved by carrying out some diagnostic tests. Such diagnostic tests are auto-correlation test, normality test, heteroscedasticity test, and multicollinearity test. The Jarque-Bera test is used to test for normality. This test indicates either a positive or a non-violation of the OLS model's assumption of normality regarding the residual from the equation.

$$\mathrm{JB} = \mathrm{n}\left[\frac{\mathrm{S}^2}{6} + \frac{(\mathrm{K}-3)^2}{24}\right] \qquad (10)$$

In the given context, the symbol "n" denotes the sample size, "S" indicates the coefficient of skewness, and "K" is the kurtosis coefficient. The null hypothesis posits that the residuals follow a normal distribution. The hypothesis of normal distribution for the residuals may be rejected when the p-value associated with the Jarque-Bera (JB) statistic is sufficiently small, indicating that the probability of seeing such extreme deviations from normality is unlikely. This rejection occurs when the p-value is not equal to zero. Nevertheless, when the p-value is quite large, often indicating a value closer to zero, the assumption of normalcy is deemed acceptable.

In terms of "auto-correlation" or "serial correlation", which is a description of patterns in errors,

Mathematically, $\mathrm{E}(\varepsilon_i, \varepsilon_j) \neq 0$

Where $\varepsilon_{i,j}$ are error terms. Hypothesis, H_0 means no autocorrelation, i.e., the F-statistic value is minimal, and P-value is > 0.05.

The use of the Variance Inflation Factor (VIF) is employed to assess the presence of multicollinearity, a statistical test used to determine the connection between independent variables inside a model. The Variance Inflation Factor (VIF) is a statistical metric that quantifies the extent of variance inflation, hence identifying the presence of multicollinearity in a multivariate regression model for each individual predictor.

For ith predictor, VIF is:

$$VIF_i = \frac{1}{1 - R^2{}_i}$$

Where $R^2{}_i$ is the R-Squared result generated for the predictors.

The variable would be considered highly collinear if the VIF is higher than the number 10. This is the general rule of thumb, VIF = 1; there is no relationship between the i^{th} predictor and the other predictor variables; variance of bi is not inflated. For a regression model with a large range of values, heteroscedasticity often occurs. It happens when there is an uneven distribution of the residual variance of the measured values. In the regression model, the "equal variance" presumption is applied. White's General Heteroscedasticity test was applied for this study to check for heteroscedasticity. The null Hypothesis, $H_{0,}$ states that there is no heteroscedasticity. If the p-value is higher than 0.05, accept the null hypothesis. The third stage of the examination of the energy-economic growth nexus is the causality test. The cointegration equation generates the lagged error correction term.

The set of causality equations, therefore, considers the long-term information that was lost during the discretization of the variables for stationarity considerations. When the variables are cointegrated, this step is required. Cointegration implies that there is a causal relationship that exists. However, with just Cointegration, there is a limitation in the sense that it does not state the direction of the causal flow. To acquire the residuals that will be used as the Error Correction Term (ECT) in the ARDL equations, it is important to first perform another set of regressions before continuing. The direction of the causal flow can be examined and determined using a variety of methods. After integrating the variables, the use of the Vector Error Correction Model (VECM), which is a constrained version of Vector Autoregression (VAR), becomes a very useful option. The dependent variable in this model is dependent on its lag values, the independent variables' lag values, the lag values of the error correction term, and the lag values of the residual term. The results of the data validation tests are presented in Table 1.0 below.

2.4. ARDL Model Procedure and Evaluation

The Auto-regressive Distributed Lag (ARDL) modelling is evaluated using the E-views software. It provides a cutting-edge, user-friendly, object-oriented interface that gives financial institutions, businesses, governments, and academics access to robust statistical time series, forecasting, and modelling capabilities. The following are the three choices for the decision criteria:

1. Cointegration can be inferred if the estimated F-stat value is above the critical value for the upper bound I(1).

2. If the F-stat value is lower than the critical value of the lower bound I(0), then we infer that there is no cointegration. The implication of this is that there is no long-term relationship between the dependent and independent variables.
3. If the F-stat value falls in between the values of the two bounds, i.e., upper bound I(1) and lower bound I(0), the verdict is that the test is inconclusive.

Table 1. Outcome of data validation tests

S/No.	Type of Test	Justification	Method	Outcome	Comment
1	Lag Length Determination.	Determine optimum lag length.	Lowest Akaike Information Criterion (AIC)	Lag order of 2 - 5 was observed.	Suitable for Quarterly time-series data.
2	Test for Stationarity.	Check for Stationarity.	Unit Root Tests: ADF (1979) & PP (1988) tests.	Reject Null hypothesis.	All variables are stationary.
3	Cointegration	Check for long-run relationships.	Bound F-Statistic test.	Cointegration observed.	Long-run relationship exists – Causality.
4	Normality Test	Error terms normally distributed?	Jacque-Bera (JB)	Accept Null hypothesis.	Normally distributed.
5	Heteroscedasticity	Standard deviations are non-constant.	White's general test.	P-values are higher at 5%.	No heteroscedasticity.
6	Autocorrelation	Checking for Serial correlation.	Breusch-Godfrey SC LM	Reject null hypothesis.	Not Serially correlated.
7	Multicollinearity	Independent variables correlated?	Variance Inflation Factor (VIF)	VIF <10	No multicollinearity.

Source: Author's compilation

Table 2. Statistical summary of the variable

	GDP
Mean	7.5400*
Median	0.5913
Maximum	11.5995
Minimum	-7.4246
Std. Dev.	3.9126
Skewness	0.3063
Kurtosis	3.1169
Jarque-Bera	1.9938
Probability	0.3690
Sum	
Sum Sq. Dev	
Observations	123

**Raised to e-15*
Source: Authors Computation, 2023 (Eviews-10)

3. Results and Discussion

The descriptive statistics outcome is presented in Table 2 below. The data indicates a wide variance between the lowest and maximum values. It also shows that the dependent variable is positively skewed. In addition, the probability from the JB (Jarque-Bera) statistics indicates a scenario of normal distribution with the variable.

3.1. Optimal Lag Length Determination

In most cases, one or two lags are sufficient for determining the ideal lag length for annual data, while one to eight lags are suitable for quarterly data [19].

Table 3.0 below provides data from the optimal lag length determination for the GDP, from lag one (1) to lag eight (8), along with the corresponding AIC (Akaike Information Criterion), SC (Schwarz Criterion), Hannan-Quinn criterion values, and selected ARDL models.

The minimum AIC value, a critical criterion, implies an optimum lag length. For the figure below, Lag 1 has the lowest AIC number; hence, it determines the lag order selection.

4. Empirical Analysis

4.1. Unit Root Test

Standard time series unit root tests can be used to analyse the electricity consumption data, together with the variables. This study uses the augmented Dickey and Fuller (ADF) (1979) test and the Phillips and Perron (1988) (PP) test. Using the separate unit root tests helps in ensuring robustness. Some researchers have concluded that most time-series data used for econometric analyses are often not stationary at level. That is the main basis for the use of the unit root test. It helps with checking if the data series is stationary before it is used in the modelling exercise.

Table 3. Optimal lag length selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2738.421	NA	4.03e+15	47.28312	47.37807	47.32166
1	-2089.473	1241.953	7.34e+10*	36.37022*	36.84497*	36.56294*
2	-2074.896	26.89154	7.53e+10	36.39476	37.24932	36.74166
3	-2070.528	7.756848	9.22e+10	36.59531	37.82968	37.09639
4	-2061.295	15.76010	1.04e+11	36.71198	38.32615	37.36724
5	-2029.103	52.72721*	7.94e+10	36.43282	38.42680	37.24226
6	-2021.659	11.67981	9.30e+10	36.58033	38.95412	37.54395
7	-2015.830	8.743037	1.13e+11	36.75570	39.50929	37.87350
8	-2010.152	8.126399	1.37e+11	36.93365	40.06705	38.20563

*Indicates lag order selected by the criterion.
LR: sequential modified LR test statistic (each test at 5% level).
FPE: Final prediction error.
AIC: Akaike information criterion.
SC: Schwarz information criterion.
HQ: Hannan-Quinn information criterion.

Source: Compiled based on the Authors Computation (Eviews-10)

From the results, all the variables were initially NS (not stationary) at the level. However, going by the p-values, critical values and ADF statistics values, at 5% critical value, they became S (stationary) at first differencing.

4.2. Cointegration Test

To determine the existence of any long-run correlation between the dependent and independent variables, the Bound F-statistics computation, used for the cointegration test, helps in determining or checking for the existence of any long-run relationship between the variables under investigation. Each of the variables was subjected to this bound F-statistic, with some being treated as endogenous variables and others as exogenous.

Again, suppose the value of the F-statistic is less than the lower critical bound I(0). In that case, that indicates the existence of no cointegration between the variables, but if it is higher than the upper critical bound I(1), there is cointegration. However, if the value is between the upper I(1) and lower I(0) critical bounds, the result is inconclusive.

For this study, the F-statistic values in Table 4 below are higher than the upper critical bound value at all the significance levels. Therefore, the analysis concludes that a long-run correlation exists between electricity consumption and the dependent variables.

Table 4. Cointegration bounds test

		Value	Significance level	I(0)	I(1)
Real GDP Growth Rate	F-statistic	5.014499	10%	2.37	3.2
	K	3	5%	2.79	3.67
			2.50%	3.15	4.08
			1%	3.65	4.66

Source: Authors Computation, 2023 (Eviews-10)

4.3. Analysis of Long-run Dynamics

The results generated in Table 5.0 below, which show the coefficients, standard error, t-statistic, and probability estimates, are useful and help with the estimation of the long-run coefficients of the ARDL model. Following that, the analysis of the relationship between the two sets of variables was carried out using the model. The model represents a double-log ARDL model for the GDP rate. The above results indicate that, on a long-run basis, the co-efficient value of commercial consumption is 74.96 with its p-value of 0.063, indicating that commercial consumption has both a significant and positive impact on the GDP rate in Nigeria. Moreover, the co-efficient value for industrial consumption is -10.289 with its p-value of 0.047, and the co-efficient value for residential consumption is -58.84 with a p-value of 0.76, which both imply a negative and significant impact on the GDP rate in Nigeria.

After establishing the existence of a long-run correlation between the variables, it becomes important to estimate the short-run coefficient of the model further.

4.4. Analysis of Short-run Dynamics

In the short-run relationship, the result in Table 6 shows the coefficients, standard error, t-statistic, and probability estimates for each selected model. The R-squared, adjusted R-squared, F-statics, and Probability (F-stats) values are also presented. The model's results indicate that the co-efficient value of commercial consumption is 0.74965, and its p-value is 0.0634. This indicates that electricity consumption by the commercial sector has a positive and insignificant impact on the GDP rate in Nigeria. Also, the co-efficient value for industrial consumption is -10.28989 with its p-value of 0.0477, and the co-efficient value of residential consumption is -58.84914 with its p-value of 0.7607, which implies a negative and significant impact and insignificant and negative impact respectively on the GDP rate in the country. The R-squared indicates that 86.65% of the variation in the GDP rate in Nigeria is accounted for by the variations in commercial, industrial, and residential electricity consumption. With a value of 63.1381 and a P-value of 0.0000, the F-statistic also shows the significance of the ARDL model.

Table 5. ARDL long run coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLOG (COMM. & STREET LIGHTING)	74.96544	58.37399	1.284227	0.0634
DLOG (INDUSTRIAL CONSUMPTION)	-10.28989	12.56262	-0.81909	0.0477
DLOG(RESIDENTIAL)	-58.84914	45.41946	-1.29568	0.7607
C	-38.84505	67.83895	-0.57261	0.0793

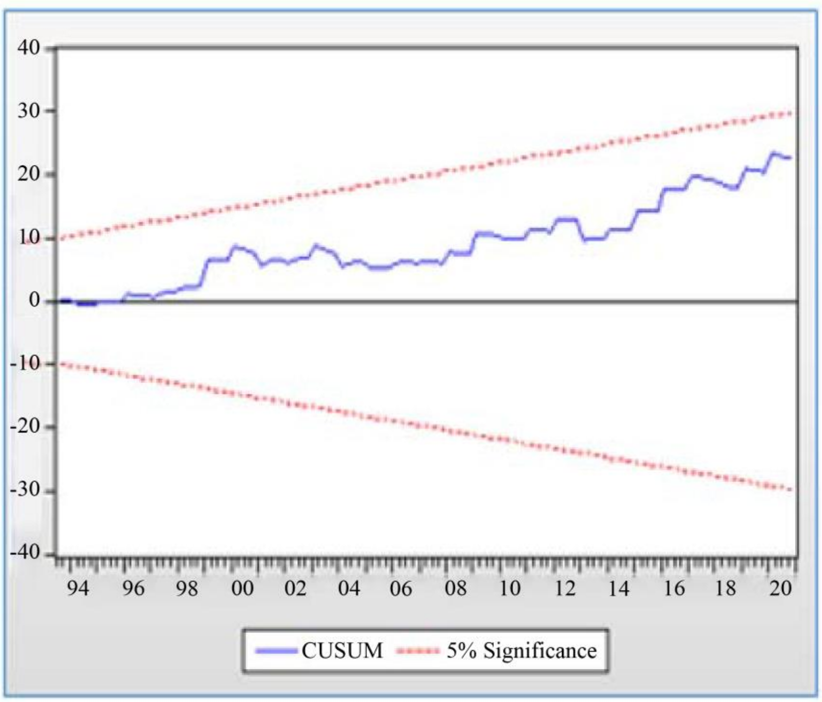
Source: Authors Computation, 2023 (Eviews-10)

Table 6. ARDL short run coefficients

GDP				
Variable	**Coefficients**	**Std. Error**	**t-Statistic**	**Prob.**
LOG (RDGP)	0.872539	0.060789	14.35357	0
LOG (COMM.AND_STREET)	0.74965	0.0866	-3.94142	0.0634
LOG (IND. CONSUMPTION)	-10.28989	0.02941	4.148898	0.0477
LOG (RESIDENTIAL)	-58.84914	0.03347	3.724796	0.0760
C	0.03092	0.0772	-0.63787	0.0793

R^2 = 0.866504, Adjusted R^2 = 0.85278, F-Statistic = 63.13814, Prob (F-Stat) = 0

Source: Authors Computation, 2023 (Eviews-10)



Real GDP growth rate

Fig. 4 A plot of the Real GDP growth rate

Source: Author's compilation, Eviews-10 output.

4.5. Stability Diagnostic Test

The CUSUM graph was used for the stability test in this study. The stability seen in the models over the 30 years (1990 to 2020) is depicted in Figure 4. The model for the real GDP rate was stable throughout the duration of the time series, as the CUSUM line did not cross the 5% significance line, thereby displaying stability.

4.6. Residual Diagnostic Test

Regression is predicated on several assumptions, including the correlation between the error terms, the normal distribution and the constant variance of the residual, including the correlation between the explanatory variables. To verify these claims, second-order test techniques like multicollinearity test, normality test, heteroscedasticity test and autocorrelation test are used.

To ascertain if the error terms are normally distributed, the normality test becomes very useful. The Jacque-Bera (JB) statistics test is used in this study to test for normality.

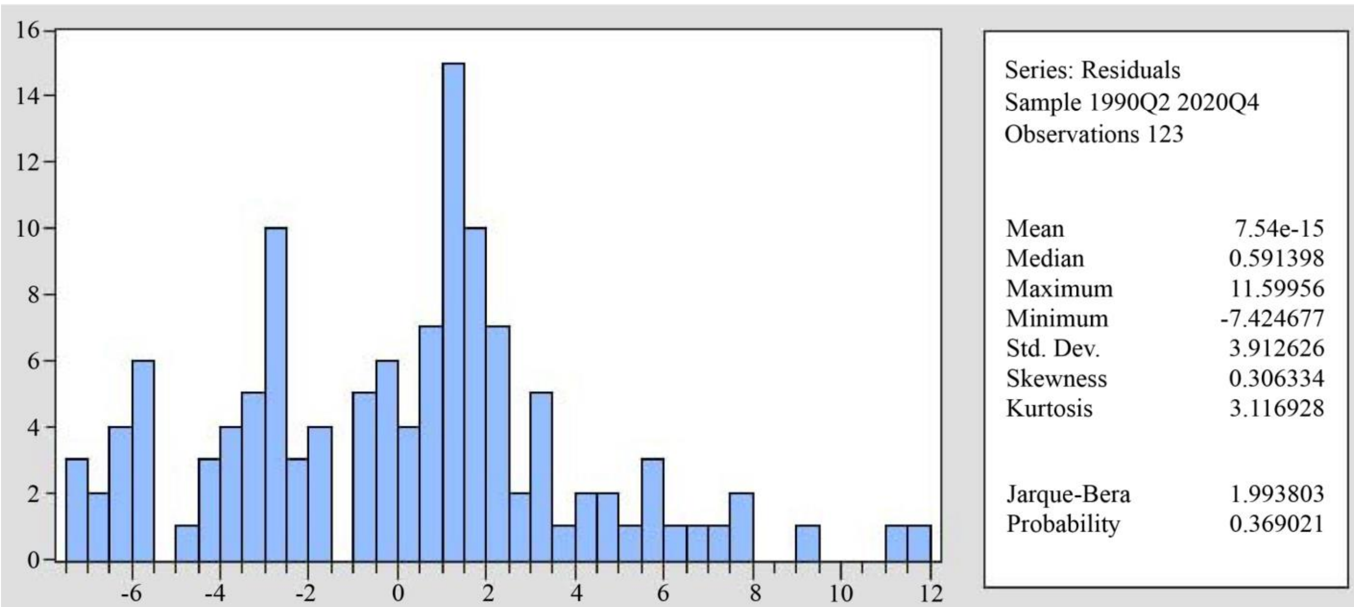


Fig. 5 Jarque-Bera normality test

Source: Authors compilation, based on Eviews-10 output

As shown in Figure 5 above, the P-value of 0.369021 (36.9021%) is higher than the 5% significance threshold level. This implies that the null hypothesis is accepted, meaning that the error term follows a normal distribution.

White's general heteroscedasticity test was used to conduct this test. To determine whether heteroscedasticity was present, the observed R-squared value and its probability were assessed. The null hypothesis is rejected at a 5% significance level; hence, there is no heteroscedasticity. This also indicates that the probabilities of the respective observed R-squared values for the dependent variables were higher than 0.05 (5%). It is possible to determine whether error terms from different periods are correlated with one another by using Serial Correlation. To achieve this, the Breusch-Godfrey serial correlation LM test was used. From this test, the residuals were found to be serially uncorrelated, meaning that the null hypothesis is not rejected at the 5% level of significance. Since all the independent variables are supposed to be independent, the multicollinearity test is required to determine whether they are correlated with one another. Variance inflation factor (VIF) was used in carrying out the multicollinearity test. The multicollinearity test operates under the general principle that multicollinearity is highly likely once the VIF exceeds 10. When multicollinearity was tested using the centered VIF, all the independent variables had values lower than 10, which suggests that multicollinearity is not present.

5. Conclusion

The goal of this study was to use the ARDL model to study the existence of a causal relationship between electricity consumption and economic growth in Nigeria, expressed in real GDP. Based on the study's results and using the ARDL model, time-series data were examined and found to be stationary at first order, necessitating a cointegration test. The cointegration test reveals that there is a long-run relationship that exists between the variables. An error correction modelling (ECM) was carried out, and it conforms to a negative and is statistically significant at a 5% significance level. Electricity consumption by the commercial sector has a short-term negative and insignificant effect on GDP;

consumption by the industrial sector positively and significantly correlates with GDP.

Electricity consumption by the commercial sector has a long-term, significant, and negative relationship with GDP. Industrial sector consumption has a significant and positive impact on GDP. Residential consumption has a significant positive correlation with GDP. The findings from this study align with the position of similar works carried out by [9], [16], [7], [23], [8], and [18], as they all found the existence of a long-term relationship between the variables, they were all statistically significant based on the Error Correction Model (ECM), with unidirectional causality based on the GDP. The conclusion from these studies is that more electricity consumption in Nigeria would lead to faster economic expansion. Based on the outcome of this study, which highlights the significant correlation between electricity consumption and economic growth indices, it is critical for the Nigerian government to implement some strategic initiatives to promote investments in the electricity sector. It is also important to strengthen the Government MDAs (ministries, departments, and agencies) that oversee the electricity sector to enable them to implement critical reforms in the sector that would help boost economic growth in Nigeria.

References

[1] Samuel Adams, Edem Kwame Mensah Klobodu, and Eric Evans Osei Opoku, "Energy Consumption, Political Regime, and Economic Growth in Sub-Saharan Africa," *Energy Policy*, vol. 96, pp. 36-44, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[2] Godwin Effiong Akpan, and Usenobong Akpan, "Electricity Consumption, Carbon Emissions and Economic Growth in Nigeria," *International Journal of Energy Economics and Policy*, vol. 2, no. 4, pp. 292-306, 2012. [Google Scholar] [Publisher Link]

[3] Hamisu Sadi Ali, Siong Hook Law, and Talha Ibrahim Zannah, "Dynamic Impact of Urbanization, Economic Growth, Energy Consumption, and Trade Openness on CO2 Emissions in Nigeria," *Environmental Science and Pollution Research*, vol. 23, pp. 12435-12443, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[4] O.O. Adegbemi, A.J. Olalekan, and O.O. Babatunde, "Causal Nexus Between Energy Consumption & Nigeria's Economic Growth," *European Scientific Journal*, vol. 9, 2019.

[5] Adegbemi Babatunde Onakoya et al., "Energy Consumption and Nigerian Economic Growth: An Empirical Analysis," *European Scientific Journal*, vol. 9, no. 4, p. 25-40, 2013. [Google Scholar] [Publisher Link]

[6] Agbede Moses Oyeyemi, "Disaggregate Energy Supply and Industrial Output in Nigeria," *International Journal of Economics, Business, and Management Research*, vol. 2, no. 2, pp. 154-172, 2018. [Google Scholar] [Publisher Link]

[7] Yusuf Opeyemi Akinwale, Olalekan Aquila Jesuleye, and Willie Siyanbola, "Empirical Analysis of the Causal Relationship between Electricity Consumption and Economic Growth in Nigeria," *British Journal of Economics, Management and Trade*, vol. 3, no. 3, pp. 277-295, 2013. [Google Scholar] [Publisher Link]

[8] Kehinde John Akomolafe, and Jonathan D. Danladi, "Electricity Consumption and Economic Growth in Nigeria: A Multivariate Investigation," *International Journal of Economics, Finance and Management*, vol. 3, no. 4, pp. 177-182, 2014. [Google Scholar] [Publisher Link]

[9] Olalekan Bashir Aworinde, "*Are Energy Consumption and GDP Per Capita Asymmetric? Empirical Evidence from Nigeria*," Department of Economics, Tai Solarin University of Education, Nigeria and University of Bath, UK, 2002. [Google Scholar]

[10] Christian Bayer, and Christoph Hanck, "Combining Non-Cointegration Tests," *Journal of Time Series Analysis*, vol. 34, no. 1, pp. 83-95, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[11] Emmanuel Abara Benson, $350 Billion is needed to Expand Electricity Generation and Distribution in Sub-Saharan Africa, Business Insider Africa, 2022. [Online]. Available: https://africa.businessinsider.com/local/markets/dollar350-billion-is-needed-to-expand-electricity-distribution-in-sub-saharan-africa/b3n0ysj

[12] Moussa P. Blimpo, and Malcolm Cosgrove-Davies, *Electricity Access in Sub-Saharan Africa: Uptake, Reliability, and Complementary Factors for Economic Impact*, Africa Development Forum Series, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[13] Benn Eifert, Alan Gelb, and Vijaya Ramachandran, "The Cost of Doing business in Africa: Evidence from Enterprise Survey Data," *World Development*, vol. 36, no. 9, pp. 1531-1546, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[14] Robert Engle, and Clive Granger, "*Long-Run Economic Relationships: Readings in Cointegration*," Oxford University Press, Oxford, England, 1991. [Google Scholar] [Publisher Link]

[15] Faisal Faisal, Turgut Tursoy, and Ozlem Ercantan, "The Relationship between Energy Consumption and Economic Growth: Evidence from Non-Granger Causality Test," *Procedia Computer Science*, vol. 120, pp. 671-675, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[16] Olusegun Odularu Gbadebo, and Chinedu Okonkwo, "Does Energy Consumption Contribute to Economic Performance? Empirical Evidence from Nigeria," *Journal of Economics and International Finance*, vol. 1, no. 2, pp. 44-58, 2009. [Google Scholar] [Publisher Link]

[17] C.W.J. Granger, "Some Recent Developments in a Concept of Causality," *Journal of Econometrics*, vol. 39, no. 1-2, pp. 199-211, 1988. [CrossRef] [Google Scholar] [Publisher Link]

[18] Bernard Njindan Iyke, "Electricity Consumption and Economic Growth in Nigeria: A Revisit of the Energy-Growth Debate," *Energy Economics*, vol. 51, pp. 166-176, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[19] Jeffrey M. Wooldridge, *Introductory Econometrics: A Modern Approach*, Fifth Edition, 2012. [Publisher Link]

[20] Luís Miguel Marques, José Alberto Fuinhas, and António Cardoso Marques, "Augmented Energy-Growth Nexus: Economic, Political, and Social Globalization Impacts," *Energy Procedia*, vol. 136, pp. 97-101, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[21] Mesbah Fathy Sharaf, "Energy Consumption and Economic Growth in Egypt: A Disaggregated Causality Analysis with Structural Breaks," *Topics in Middle Eastern and African Economies*, vol. 18, no. 2, pp. 61-86, 2016. [Google Scholar] [Publisher Link]

[22] Obas John Ebohon, "Energy, Economic Growth, and Causality in Developing Countries: A Case Study of Tanzania and Nigeria," *Energy Policy*, vol. 24, no. 5, pp. 447-453, 1996. [CrossRef] [Google Scholar] [Publisher Link]

[23] N.E. Okoligwe, and Okezie A. Ihugba, "Relationship between Electricity Consumption and Economic Growth: Evidence from Nigeria 1971-2012," *Academic Journal of Interdisciplinary Studies,* vol. 3, no. 5, pp. 137-152, 2014. [Google Scholar] [Publisher Link]

[24] Abel Oyuke, Peter Halley Penar, and Brian Howard, "Off-Grid or 'Off-On': Lack of Access, Unreliable Electricity Supply Still Plagues Majority of Africans," Afrobarometer Survey, 2016. [Google Scholar] [Publisher Link]

[25] M. Hashem Pesaran, and Yongcheol Shin, "*An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis*," Econometric and Economic Theory in 20th Century, The Ragnar Frisch Centennial Symposium, Cambridge University Press, Cambridge, pp. 387-413, 1999. [CrossRef] [Google Scholar] [Publisher Link]

[26] M. Hashem Pesaran, Yongcheol Shin, and Richard J. Smith, "Bounds Testing Approaches to the Analysis of Level Relationships," *Journal of Applied Econometrics*, vol. 16, no. 3, pp. 289-326, 2001. [CrossRef] [Google Scholar] [Publisher Link]