Electricity Consumption and Nigeria's Economic Growth: Causality Test Based on VECM Framework

AbdulQadir Idris Abdullahi[1], Bello Malam Sa'idu & Ibrahim Muhammad Adam

Department of Economics & Development Studies,
Faculty of Arts and Social Sciences,
Federal University Dutse,
Jigawa State, Nigeria.

Abstract

This paper applies the VECM framework to examine the causal relationship between electricity consumption and GDP for Nigeria during 1981–2014. Our estimation results indicate that economic growth and electricity consumption are cointegrated and there is short run unidirectional Granger causality running from electricity consumption to economic growth in the short run but not vice versa. The paper suggests that investing more and reducing inefficiency in the supply and use of electricity can further stimulate economic growth in the country. The results should, however, be interpreted with caution because of the possibility of loss in power associated with the small sample size and the danger of omitted variable bias that could result from the use of bi-variate analysis.

Keywords: Energy, Electricity Consumption, Economic Growth, VECM.
JEL Classification: C22, C32, O13, O40, Q43.

Contribution/Originality:
The study is first of its kind to combine conventional models; Vector Autoregressive (VAR), Granger causality, unit root, Error Correction Model (ECM) and Vector Error Correction Model (VECM) applied to Nigeria within the context of energy research. Also, it contributes in the existing literature on electricity consumption and economic growth in the country. Thus, it has contributed in energy sector policy treatise.

1.0 Introduction

In the past three decades, Nigeria had undergone a tremendous declined in economic growth because of the dilapidated power sector induced by neglect and corruption that staples the sector development and growth. These also witness the transition from state owned power generation industry in the forenamed of Nigerian Electricity Power Authority (NEPA) to a rebranded Power Holding Company of Nigeria (PHCN) efforts by the state to liberalize the marketing section of the sector for growth potential. The effect of growth in socio-economic sectors have direct link to the growth of energy/electricity in context of developing countries and as in the case of Nigeria. The impact can never be separated from the effect of inadequate power supply that manifested in achieving low economic growth in third world countries as compare to high energy intensive countries as witnessed by the world two giants i.e. China and the United States.

Historically, the electric power industry was designated as a driving force for industrialization of Nigeria's manufacturing and Agricultural sectors and at the same time supports medium and scale enterprise. Power shortages had contributed to the collapsed manufacturing and service sectors via increasing the cost of production (Ogundipe & Apata, 2013). There has been increasing demand for electricity in Nigeria given the present government of Muhammadu Buhari campaign promised to increase the mega-watts to around 7000MW by 2019. In the past three decades, there also a growing interest in the study of the causal relationship between energy consumption and economic growth but surprising that so far there has been little empirical work on Nigeria. The purpose of this paper is to

[1] Corresponding Author's Email and Phone: abdulqadir.idris@fud.edu.ng; +234 (0) 807 348 8335.

contribute to the field of energy economic with an econometric framework on the causal relationship between electricity and income, evidence from Nigeria.

At present, the Nigerian government has a policy target of achieving a sustained increase mega-watt from less than 2000MW in the past three decades to 7000 MW by 2019. This implies that total output growth as expected with the promise kept, and the study of the causal relationship between electricity consumption and GDP will guide the pathway as well as the better understanding of the role of electricity in Nigeria's economic growth. The results of causality tests can shed light on the future electricity policies, such as energy savings, alternation power sourcing, plan capacity expansion and the construction of nationwide interconnection of power networks. However, it is of significance to understand the relationship between electricity and income of a common trader, craftwork ship, workshops that rely on power grid to function, should Nigeria want to avoid the electricity shortages that occasioned to hamper these economic activities at grassroots level as a first-round effect and the second-round effect on economic growth as its used to be in the past three decades.

2.0 Literature Review

There has been a large body literature on energy consumption and economic growth in the field of econometrics, and in particular with seminal work postulated by Kraft & Kraft (1978), in which causality was found to run from GNP to energy consumption in the United States. The empirical studies were later extended to cover other industrial countries like the United Kingdom, Germany, Italy, Canada, France, India, China and Japan (Ghosh, 2002; Chontanawat, Hunt & Pierse, 2006; Payne, 2009; Soytas & Sari, 2006; Apergis & Payne, 2011). In subsequent studies, instead of relying on the standard Granger causality test, the cointegration and error-correction models were applied to test for stationarity of the variables in the time-series. Moreover, some studies (Sebri & Ben-Salha, 2014; Lean & Smyth, 2010; Ciarreta & Zarraga, 2010) tested for Granger causality in a multivariate setting by using a vector auto regression model.

In addition to the above literature, many studies still focus deeply on the specific causal link between electricity consumption and economic growth from the early 90s. Payne (2010), identified more than 40 papers and synthesized the literature on electricity consumption-growth nexus. As in the energy growth relationship, three types of results may also appear unidirectional causality from electricity to GDP (EG) or from GDP to the electricity sector (GE), bidirectional causality (BD) and the absence of causality (AC). He shows that the majority of studies support the non-neutrality hypothesis (69%). Thus, in the EG unidirectional causality case, it can be seen that the studies cover different countries and use Granger causality to highlight the fact that the electricity sector may be a limiting or accelerating factor of economic growth (Altinay & Karagol, 2005; Ho & Siu, 2007; Yuan, Kang, Zhao & Hu, 2008; Ciarreta & Zarraga, 2010; Agbloyor *et al*, 2013).

In the case of unidirectional causality of type GE, it appears that an energy saving, and electricity consumption reduction policy does not affect the growth of economic activity, that is the GDP is not explained by electricity (Ghosh, 2002; Jumbe, 2004; Narayan & Smyth, 2005; Yoo & Kim, 2006; Mozumder & Marathe, 2007; Ho & Siu, 2007; Halicioglu, 2009; Dagher & Yacoubian, 2012). In the case of bidirectional causality (BD), electricity consumption explains economic growth and vice versa, the GDP growth leads to increased power consumption. In this case, there is a two-way relationship with both factors being closely related (Jumbe, 2004; Lee, 2005; Shahbaz *et al*, 2011; Ben Aïssa *et al*, 2014; Pempetzoglou, 2014; Tang *et al*., 2013). Finally, in the AC causality case, there is no causal relationship between the electricity sector and the GDP, showing a neutral hypothesis (Murray & Nan, 1996; Wolde-Rufael, 2006; Lee & Chang, 2005; Prasad, 2008).

The analysis of empirical data reveals that the relationship between electricity consumption and the GDP is not clearly identified, but a number of papers support the causality link. The emergence of conflicting results for the same country can be explained by the different periods chosen, the estimation methods for cointegration and causality, the set of variables and above all the country's specific energy policy and institutional frame-work (Ozturk, 2010; Belloumi, 2014) Notably, (Keho, 2007; Boyce 2001) using Toda-Yamamoto framework and Wolde-Rufael (2009) using data on African countries illustrated that there is a causality running from economic growth to energy consumption in Cote d'Ivoire. A different methodological framework shows a bidirectional causality within a bound testing approach and a Toda-Yamamoto causality test (Esso, 2010) while (Li, Nan, & Nan, 2011) yields a lack of causation for the same country. It is therefore necessary to consider the nature of the relationship between electricity and the GDP dynamics in Cote d'Ivoire to implement the strategies with regard to existing causality and direction (Kouakou, 2011; Eggoh *et al*, 2011; Eberhard & Shkaratan, 2012; Deichmann *et al*., 2011; Ben Aïssa *et al*., 2014; Belloumi, 2009; Bélaïd & Abderrahmani, 2013; Al-Mulali & Ozturk, 2014; Azoumah *et al*., 2011).

3.0 Methodology

According to Engle & Granger (1987), a linear combination of two or more non-stationary series (with the same order of integration) may be stationary. If such a stationary linear combination exists, the series is cointegrated and long run equilibrium relationships exist. Incorporating these cointegrated properties, a vector error-correction model (VECM) could be constructed to test for Granger causation of the series in at least one direction. In this paper, the ECM is specifically adopted to examine the Granger causality between real GDP and electricity consumption in Nigeria.

Since the use of the ECM requires the series to be cointegrated with the same order, it is essential to first test the series for stationarity and cointegration. A series is said to be nonstationary (or stationary) if it has non-constant (or constant) mean, variance, and autocovariance (at various lags) over time. If a nonstationary series must be differenced d times to become stationary, then it is said to be integrated of order d: i.e. I(d). The augmented Dickey–Fuller (ADF) (Dickey and Fuller, 1979; Said and Dickey, 1984) and Phillips Perron (PP) tests have been applied to examine unit roots and stationarity in this paper. Thus, for both tests, we are testing the null hypothesis H_0, that y_t is nonstationary, against H_1, that y_t is stationary (Enders, Chung, Enders, Shao & Yuan, 2004).

When both series are integrated of the same order, we can proceed to test for the presence of cointegration. The Johansen maximum likelihood procedure (Johansen, 1988; Johansen and Juselius, 1990) is used for this purpose. Any long-run cointegrating relationship found between the series will contribute an additional error–correction term to the ECM. The Johansen procedure is a vector autoregressive (VAR) based test on restrictions imposed by cointegration in the unrestricted VAR. The null hypothesis in consideration is H_0, that there are a different number of cointegration relations, against H_1, that all series in the VAR is stationary (Enders, 2010).

The existence of cointegration relationships indicates that there are long-run relationships among the variables, and thereby Granger causality among them in at least one direction. The ECM was introduced by Sargan (2016) and later popularized by Engle & Granger (2018). It is used for correcting disequilibrium and testing for long and short-run causality among cointegrated variables (Enders, 2004).

The ECM used is specified as follows:

$$\Delta y_t = \psi_2 + \psi_y \mu_{t-1} + \sum_{i=1} \psi_{21}(i)\Delta y_{t-i} + \sum_{i=1} \psi_{22}(i)\Delta x_{t-i} + \varepsilon_{yt} \quad (1)$$

$$\Delta x_t = \psi_1 + \psi_x \mu_{t-1} + \sum_{i=1} \psi_{11}(i)\Delta x_{t-i} + \sum_{i=1} \psi_{12}(i)\Delta x_{t-i} + \varepsilon_{xt} \quad (2)$$

Where; y_t and x_t represent natural logarithms of real GDP and electricity consumption, respectively, and (Δy_t, Δx_t) are the differences in these variables that capture their short-run disturbances. ε_{yt}, ε_{xt} are the serially uncorrelated error terms, and μ_{t-1} is the error correction term (ECT), which is derived from the long run cointegration relationship and measures the magnitude of the past disequilibrium[2].

$$y_t = \beta_0 + \beta_1 x_t + \mu_t \quad (3)$$

In each equation, change in the endogenous variable is caused not only by their lags but also by the previous period's disequilibrium in level, i.e. μ_{t-1}. Given such a specification, the presence of short and long-run causality could be tested. Consider Eq. (1), if the estimated coefficients on lagged values of electricity consumption are statistically significant, and then the implication is that the electricity consumption Granger causes real GDP in the short-run. On the other hand, long-run causality can be found by testing the significance of the past disequilibrium term.

Our empirical study uses the time series data of real GDP and electricity consumption for the 1981–2014 periods for Nigeria. Nominal GDP and electricity consumption data were obtained from the National Bureau of Statistics (1980–2014). In this paper, electricity consumption is expressed in terms of billion kilowatt hours (kWh) or terawatt hours (TWh).

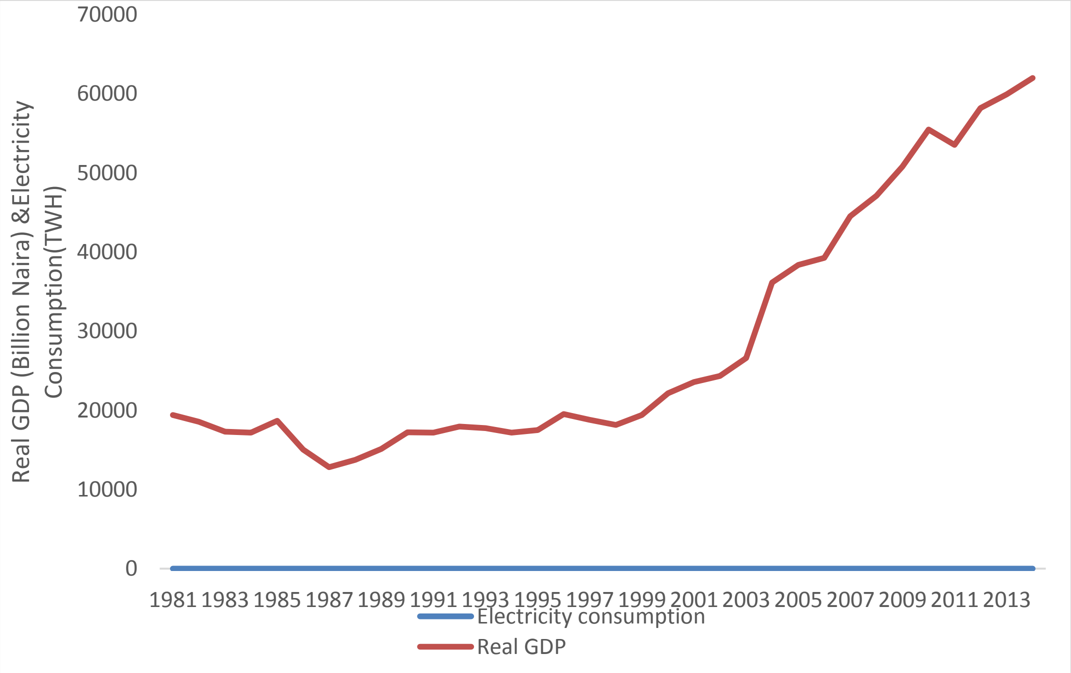

Figure 1: Electricity Consumption and Nigerian Economic Growth

[2] It is called the ECT since the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments

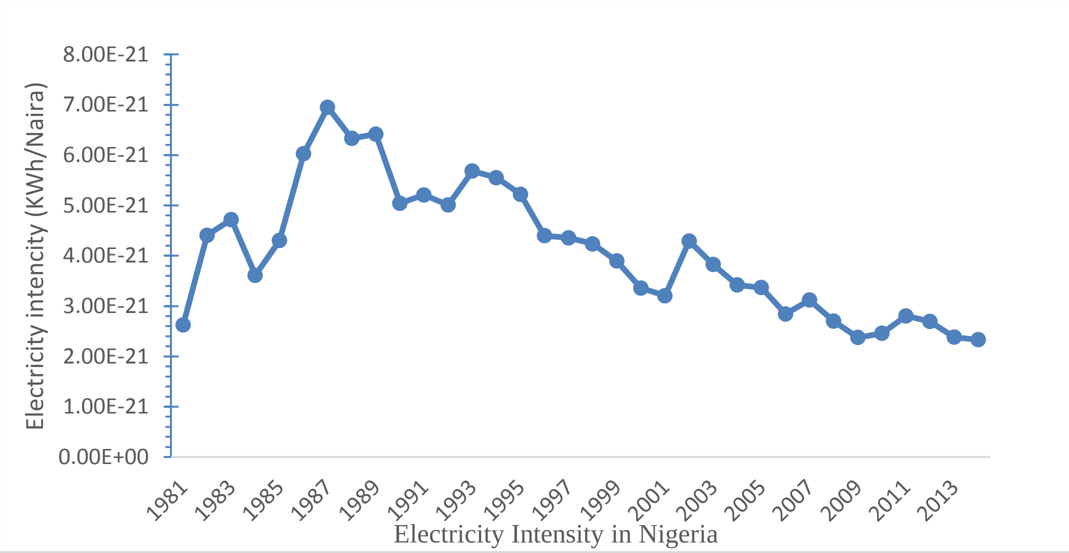

Figure 2: Energy Intensity

4.0 Data and Empirical Results

The data for this study were obtained from the World Development Indicators (WDI) of the World Bank database (2017), National Bureau of Statistics (NBS) Nigeria, annual bulletin varies collections. There are three yearly time series available namely, electricity consumption, and gross domestic product (GDP) for the period of 1981–2014. Thus, Table (1) reports the results of the ADF and PP tests on the integration properties of real GDP and electricity consumption for Nigeria. Results of the two tests indicate that the two series are found to be nonstationary. However, first differences of these series lead to stationarity.

Table 1: Result of ADF and PP Tests

Variables	Augment Dickey-Fuller (ADF)		Phillips–Perron (PP)	
	Intercept			
	Levels	First Difference	Levels	First Difference
GDP	2.106	-4.498**	1.990	-4.543**
Electricity	-0.915	-6.983***	-0.645	-7.027***
	Trend and Intercept			
GDP	-1.358	-5.745***	-1.358	-5.745***
Electricity	-2.392	-6.952***	-2.409	-6.952***

Note: The true data generating aprocess for each variable has been found by following the procedures described in Enders, 1995 For the ADF tests, the appropriate lag lengths were selected using Akaike's Information Criteria (AIC) and a maximum of up to 4 lags has been incorporated due to limited sample size. For the PP tests, truncated lags are determined using the highest significant lag (using approximate 95% confidence interval) from either the autocorrelation function or the partial autocorrelation function of the first differenced series. ** and *** Represents the rejection of the null hypothesis of nonstationarity at 5% and 1% level of significance.

Given the fact that satisfied cointegration test, as all the variables at the level, are nonstationary but when converted to the first difference they became stationary and the condition for Johansen cointegration test actualized. These indicate that the integration of real GDP and electricity consumption for Nigeria is of order one, i.e. I(1).Given that integration of the two series is of the same order, we continued to test whether the two series are cointegrated over the sample period. Table (2) shows the results of the Johansen test for cointegration.

Table 2: Result of Johansen Cointegration Test

Normalized cointegrating equation: GDP=0.75+1.02 Electricity				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5% Critical value	Prob.**
None *	0.525419	31.70276	15.49471	0.0001
At most 1 *	0.267606	9.343083	3.841466	0.0022
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	5% Critical value	Prob.**
None *	0.525419	22.35968	14.26460	0.0021
At most 1 *	0.267606	9.343083	3.841466	0.0022

Trace and Max-eigenvalue tests indicated 2 cointegrating eqnt(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values

The likelihood ratio (LR) test rejects the hypothesis of no cointegration and indicates that there is one cointegrating equation at the 5% significance level, i.e. there is a long-run relationship between economic growth and electricity consumption for Nigeria. The normalized cointegrating coefficients are shown in the last row of Table (3), and the signs of the variables conform to the theory in literature, i.e. there is a positive relationship between electricity consumption and real GDP. Following the detection of the cointegrating relationship between real GDP and electricity consumption, an ECM was set up for investigating short and long-run causality. In the ECM, the first difference of each endogenous variable (real GDP or electricity consumption) was regressed on a one period lag of the cointegrating equation and lagged first differences of all the endogenous variables in the system.

Table 3: Granger Causality Test

Source of causation					
	Short-run		ECT	Joint (short-run/ECT)	
	ΔGDP	Δ Electricity	μ_{t-1}	ΔGDP	Δ Electricity
	$F-statistcs$		$t-statistics$	$F-statistcs$	
ΔGDP	-	11.88***	-6.35***	-	11.92***
Δ Electricity	0.94	-	-0.98***	0.96	-

Note: μ_{t-1} represents the residual derived from normalizing the cointegrating vector on GDP. The optimal lag has been chosen based on AIC. Godfrey LM tests have been applied and results confirmed the absence of serial correlation in the ECM. ***Denotes significance at the 1% level.

Table (3) shows the results of the tests on causality. We have performed several tests for Granger causality:(1) long-run causality–the significance of the error-correction terms by t-test; (2) short-run causality–the significance of the sum of lagged terms of each explanatory variable by joint F test; and (3) short-run adjustment to re-establish long-run equilibrium–the joint significance of the sum of lagged terms of each explanatory variable and the ECT by joint F test. Long run causality if the coefficient of the error term sign is negative and significant then, this revealed overwhelming evidence that there is a long run causality running from electricity consumption to GDP. However, the regression output reveals correctly signed coefficient of the error term with the p-value relatively less than 5% that is enough evidence to infer that there is long run causality running from electricity consumption to GDP.

The short run causality can be determined via equation the coefficients of the independent variable to zero using WALD Test i.e. C (4) = C (5) = C (6) = 0. But the result from the Wald test revealed that the p-value of the chi-square is less than 5% which is enough evident to infer that there is a short run causality running from electricity consumption to GDP, but not the reverse, i.e. there is unidirectional

Granger causality. The coefficient of the ECT is found to be significant and negatively signed in the GDP equation, which indicates that given any deviation of GDP from the long-run equilibrium relationship both variables in the ECM would interact in a dynamic fashion to restore long-run equilibrium. Results of the significance of interactive terms of change in electricity consumption (Δ Electricity), along with the ECT in the GDP equation are consistent with the presence of Granger-causality running from electricity consumption to real GDP. These indicate that whenever there is the presence of a shock to the system, electricity consumption would make short-run adjustments to re-establish long-run equilibrium.

5.0 Conclusion

This paper applies the VECM model to examine the causal relationship between electricity consumption and economic growth for Nigeria. Prior to testing for causality, the ADF test and Johansen maximum likelihood test were used to examine for unit roots and cointegration. Our estimation results indicate that there is a unidirectional relationship running from electricity consumption to economic growth, i.e. an increase in electricity consumption would raise economic growth but not the reverse. Our empirical findings support the notion that there has been a decoupling of electricity consumption and economic growth. The rate of growth of electricity consumption is not a direct one-to-one correlation with GDP growth. The rapid growth in GDP might not trigger the similar growth in electricity consumption. This direction of causation shed light on future electricity policies regarding environmental protection, generation, transmission, and distribution.

In the period under study, around 20%–25% of the electricity consumption is for industrial production. Since industrial production contributes a small share of GDP, the growth in industrial demand for electricity increases industrial output and which, in turn, raises the real GDP of Nigeria. This implies that growth in electricity consumption will cause economic growth via industrial demand for electricity. Given this situation, any shocks to electricity supply will adversely affect industrial output and thereby reducing real GDP growth.

To avoid any adverse effect of electricity shortages on industrial production, it is important for the Nigerian government to plan and build enough generating capacity to satisfy the industrial demand for electricity. These could be achieved through attracting new capital to the power industry. Despite strong electricity consumption in the industrial sector, Nigeria has for some period experiences industries transferring to the countries where electricity supply is relatively stabled translating into the loss of employment in the sector from the industries that were either close-down or transferred. But the reverse is the case when electricity supply becomes adequate, when the income and living standards of the population increase, demand for electricity will increase via the increasing demand for electrical appliances and other consumer durable goods. But at present, many rural populaces still have no access to electricity and some areas still face the problem of power shortages. Insufficient capital investments in power generation and transmission, higher tariffs and fees imposed on consumers in rural areas have deterred the natural growth of electricity consumption. Before the mid-1990s, frequent outages in electricity supply had adversely affected industrial production and electricity consumption. Therefore, it is not surprising to find that declining real GDP growth did cause a corresponding decline in electricity consumption in Nigeria, as our results indicate.

To overcome the constraints on electricity consumption, the government has to speed up the nation-wide interconnection of power networks, to upgrade national distribution grids, and to accelerate rural electrification. Tariff reforms are needed to remove the price differentials between rural and urban areas. These policies will have the effects of improving the efficiency in power transmission and distribution, alleviating the problem of power shortages, and allowing the rural population to enjoy a higher level of electricity consumption.

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