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Energy Consumption and Economic Growth in Nigeria: A Test of Alternative Specifications

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ABSTRACT

The debate on the nexus between energy consumption and economic growth continues unabated with divergent views on the direction of the relationship. This is partly due to the sources and patterns of energy consumption across different countries, differential characteristics of the economies, and differences in the methodologies employed. Again, the mixed and inconclusive results from prior cointegration tests might have arisen from the assumption of symmetry when, in actuality, the response of economic growth to energy consumption may be asymmetric. Furthermore, for studies that employed the asymmetric cointegration analysis, the data generating process might account for the conflicting evidence, especially for annual series. Therefore, this paper re-evaluates the relationship between energy consumption and economic growth in Nigeria over the period 1999Q1-2016Q4 using alternative model specifications. Specifically, the study used a nonlinear (or asymmetric) ARDL model and an ARDL-ECM specification which presumes a linear relationship rather than a nonlinear one. Overall, we find that the role of energy consumption as a driver of growth remained negligible throughout, suggesting that a lot still needs to be done to ensure that the expected role of energy begins to manifest in the Nigerian economy. The granger causality tests revealed a unidirectional causality running from energy consumption to economic growth, indicating that Nigeria can attain high levels of sustainable growth with improved and stable energy supply. Thus, the study concludes that these findings constitute a wake-up call on governments and policymakers in Nigeria and other Sub-Saharan African economies that share structural similarities with it that there is an urgent need to evolve and implement policies that will address the energy challenges of these economies.

Keywords: Energy Consumption, Economic Growth, Nonlinear ARDL, Error Correction Model, Granger Causality
JEL Classifications: Q41, O47, C51, C22, C32

1. INTRODUCTION

The energy-growth nexus is not only an important consideration in the development dynamics of countries but also fundamental to the quality of lives in the society. This is because the value-added of energy to any economy, either as a final good (lighting, cooking, heating, air-conditioning, etc.) or as an input into the production of other goods and services, is fundamental to the quality of lives in a country. Thus, the transformational power of energy in economic growth and development of a nation when supplied in sufficient, reliable and affordable quantity for every type of productive use cannot be over stressed. Energy consumption may, in fact, be ascribed as a disparity index between developed and undeveloped economies. This is because most undeveloped economies are bedevilled by lack of energy, which not only stunts developments in education and health but also growth of enterprises and national development. Furthermore, failure to understand the nexus between energy and economic growth and development, especially in developing economies, may explain the apparent indifference in appreciating the significance and direction of causality between them. Hence, as Nigeria strives to become one of the 20 largest economies in the world by 2030, the role of energy in driving its growth and development must be more comprehensively understood. While energy is a key ingredient

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in all sectors and facets of a modern economy, the policy context requires that the nature and direction of causality between energy consumption and economic growth be properly understood in order to design effective energy policy interventions. Energy policy interventions should support the utilization of established energy sources while developing other potential sources. Incidentally, the empirical relationship between energy consumption and economic growth has yielded conflicting results in the extant literature.

The energy-growth literature generally distinguishes between three different types of nexus, namely: no causality, bidirectional, and unidirectional causalities (for example, Kraft and Kraft, 1978; Yu and Choi, 1985; Erol and Yu, 1987; Yu et al., 1988; Cheng and Lai, 1997; Keppler, 2007; Yildirim and Aslan, 2012). The neutrality (i.e., no causality) hypothesis holds mainly in the developed countries, whereas bidirectional and unidirectional causalities are found particularly in the developing countries (for instance, Kraft and Kraft, 1978; Yu and Choi, 1985). The later presupposes that energy conservation measures may be taken with no adverse shocks to economic growth, if the causality runs from GDP to energy consumption. The reverse causality could upset economic growth. For developing countries in general, both empirical research and anecdotal evidence are conclusive that energy is an important ingredient for economic development. Aggressive or progressive pursuit of economic development requires intensive industrial activities as well as improvement in service delivery which demand a substantial amount of steady energy supply. Lee (2005) submits that this direction of causation expounds future energy use concerning environmental protection and economic development.

The argument for the mixed empirical evidence or lack of consensus on the results for a specific country or groups of countries on the direction of the causality between energy access and economic growth is based on methodological differences, time periods and countries examined (in terms of their economic state or level of development) as well as the choice of variables (Aworinde, 2002; Ozturk, 2010; Payne, 2010a, b; Ouedraogo, 2013). The focus of most extant literature on the causal relationship between economic growth and energy consumption has been on symmetric cointegrating relationship, ignoring the possibility of asymmetric cointegrating relationship. Little wonder recent literature (Richard, 2012; Bayramoglu and Yildirim, 2017) adopted non-linear auto regressive distributed lag models (NARDL) in examining this relationship.

This paper contributes the following to the literature. First, it reexamines the energy consumption-economic growth relationship in Nigeria, with emphasis on the equilibrium and causal dynamics of this relationship. To this end, the paper adopts the nonlinear autoregressive distributed lag (NARDL) model recently advanced by Shin et al. (2013), which allows for the regressors to be decomposed into positive and negative partial sum processes. Second, unlike the extant literature for Nigeria, this decomposition allows for deeper understanding on how growth responds to increases and decreases in energy consumption. Clearly, such understanding will aid better policy formulation in the economy. Third, the use of the NARDL approach will somewhat control for weak endogeneity, which is usually associated with growth equations, and which the usual static cointegrating procedures cannot resolve. Fourth, unlike other commonly used tests for equilibrium relationships such as the Engle-Granger two-step procedure, the NARDL approach accommodates combinations of both stationary and non-stationary processes, and the inferences remain robust regardless of whether the regressors are I(0), I(1), or mutually cointegrated. Fifth, unlike previous studies for Nigeria such as Richard (2012), this study uses higher frequency data which allows for the speed of adjustment symmetry/asymmetry to be captured faster and better. The study also utilizes the asymmetric causality test of Hatemi-J (2012) that separates the causal impact of positive shocks from negative shocks in ascertaining the relationship between the variables. Finally, in addition to the NARDL procedure, this study uses the ARDL-ECM specification of Pesaran et al. (2001) to verify if the presumed relationship is linear rather than nonlinear. Thus, this paper uses these robust methodological frameworks to reassess the presumed energy-growth relationship in Nigeria.

The rest of the paper is structured as follows. Section 2 presents a brief overview of the relevant literature, including the theoretical and empirical contexts. Section 3 provides the methodology, while Section 4 contains data diagnostics and the analysis of empirical results. Section 5 concludes the paper and provides some policy implications.

2. AN OVERVIEW OF THE LITERATURE

2.1. Theoretical Literature

Following the seminal works of Engle and Granger (1987, 1991) on the direction of the relationship between economic growth (income) and energy consumption, many studies have found different trajectories of the causal relationship: economic growth-energy (consumption) (GDP→Energy), denoting that causality moves from economic growth to energy, that is, economic growth increases energy usage (Yu and Choi, 1985, for South Korea, Philippines; Jumbe, 2004, for Malawi; Ambapour and Massamba, 2005, for Congo; Keppler, 2007, for India); energy-growth (Energy→GDP), implying that causality moves from energy consumption to economic growth, that is, increasing energy consumption potentially leads to economic growth (Asafu-Adjaye, 2000, for India, Indonesia, and Turkey; Fatai et al., 2004, for India and Indonesia; Lee, 2005, for 18 countries; Keppler, 2007, for China); bi-directional (Energy↔GDP), meaning bi-directional causality between energy consumption and economic growth, that is, the direction of the impact from one variable on the other is bi-directional, in which case economic growth simultaneously affects energy consumption, and vice versa (Glasure and Lee, 1998, for South Korea and Singapore; Asafu-Adjaye, 2000, for Thailand and Philippines; Fatai et al., 2004, for Thailand and Philippines; Morimoto and Hope, 2004, for Sri Lanka; Oh and Lee, 2004, for South Korea; Paul and Bhattacharya, 2004, for India); and no causality in either direction, the neutrality hypothesis, implying that energy consumption does not affect growth, and vice-versa (Payne, 2010a, b; Yu and Choi, 1985; To et al., 2013).

The energy-growth literature identifies four hypotheses about the causal relationship between energy consumption and economic growth, namely: the growth hypothesis, the conservation hypothesis, the feedback hypothesis, and the neutrality hypothesis. Each of these hypotheses has important policy implications (Ozturk, 2010; Payne, 2010a, b; Yildirim and Aslan, 2012). The Growth hypothesis assumes unidirectional causality from energy to economic growth, emphasizing the crucial role energy access and consumption play on output growth. This relationship denotes an energy-dependent economy where no access or limited access to modern energy supplies potentially limits entrepreneurship and economic activities, resulting in poor economic performance (Tsani, 2010). In developing countries in particular, the reality is that energy impacts economic growth, just as economic growth triggers an increase in energy consumption. Indeed, these countries are in desperate need of steady electricity supply to power economic development. Epileptic energy supply dwarfs economic growth and development. Low or no access to dependable energy supply is a serious impediment to economic activities and development. Interpretatively therefore, energy and economic growth have reciprocal influence: increase or decrease in one variable can trigger a rise or fall in the other. In the Organisation for Economic Co-operation and Development (OECD) countries and many fast-developing economies, dependable energy infrastructure is the first necessary condition for rapid inclusive economic structural transformation. A steady electricity supply is the first affirmative engine in the infrastructure milieu that drives economic growth and transformation. In most industrialised and emerging-economy *countries,* steady supply of electricity is given such that the economic cost of a few hours of power outage, often caused by a catastrophic natural disaster, is so enormous that virtually all aspects of the local economy are impacted in terms of lost business opportunities. The growth hypothesis compels national development policy to build inclusive access to affordable modern energy to promote economic growth, prosperity, and sustainable development (Squalli, 2007).

The conservation hypothesis presumes that economic growth is the dynamic causality of the energy sector development and indicates an economy that is less energy-dependent. The empirical relevance of this hypothesis is validated through the unidirectional causality that runs from economic growth to energy consumption. Thus, energy conservation policies, such as investments in energy efficiency and demand management policies prospectively have no adverse impact on output growth (Ouedraogo, 2013). The feedback hypothesis implies a mutual and complementary relationship between energy and economic growth and is empirically supported by bi-directional causality between energy and output growth. The neutrality hypothesis indicates the absence of any impact between the energy sector and economic growth. Thus, the lack of causality between energy consumption and economic growth provides evidence for the validity of the neutrality hypothesis. In this scenario, policies to promote energy access and higher levels of consumption will not have an influence on economic growth (Ouedraogo, 2013). The neutrality hypothesis presents energy consumption as a small component of real GDP (Payne, 2010a, b; To et al., 2013), and as such should have no significant impact on economic growth. The hypothesis promotes a more service-intensive economy, which requires less energy intensity, than an economy that relies on a large manufacturing industry. However, the reality is that the neutrality hypothesis would appear to hold in advanced economies that have historically attained a sufficiently large uninterrupted energy supply which is taken for granted. Countries where constant energy supply is a big issue are less concerned about the conflict between energy supply/consumption and the environment. While the western powers seek to arbitrate between the goals of energy production/consumption and environmental quality, the causal relationships among economic growth, energy consumption and environmental quality are, for now, more of academic interest than of considerable importance in the policy of energy economics in many developing countries like Nigeria.

2.2. Empirical Literature

The empirical literature provides mixed and conflicting evidence which confirms the lack of consensus or unequivocal conclusion about the causal relationship between energy consumption and economic growth. For instance, Belke et al. (2011) examined the long-run relationship between energy consumption and real GDP, explicitly taking into account the role of energy prices for 25 OECD countries. Using annual data from 1981 to 2007 and cointegration analysis, they found that only the common components of energy consumption, economic growth and energy prices were cointegrated. Their causality tests indicated the presence of a bi-directional relationship between energy consumption and economic growth. Akkemik and Goksal (2012) argue that most panel studies on countries' energy consumption-growth nexus usually assume that panels are homogenous when, in reality, this is not always so. Their study, therefore, assumed panel heterogeneity and adopted a more advanced Granger causality technique for fixed coefficient panels. Thus, with a panel of 79 countries and data for the period 1980-2007, their results showed a bi-directional causality in 57 countries, unidirectional causality in 7 countries, and no causality in 15 countries. For the 57 countries exhibiting bi-directional causality, the interaction between energy consumption and economic growth was unambiguous.

Ouedraogo (2013) used panel cointegration technique and annual data, spanning 21 years (1980-2008), to test the long-run relationship between energy access and economic growth for the 15 member countries in the Economic Community of West African States (ECOWAS). The result showed a causality running from GDP to energy consumption in the short-run, and from energy consumption to GDP in the long-run. The study also found evidence of a unidirectional causality running from electricity consumption to GDP in the long-run. Mohammadi and Parvaresh (2014) examined the long-run relation and short-run dynamics between energy consumption and output in a panel of 14 oil-exporting countries over 1980-2007. The authors employed three alternative panel estimation techniques (dynamic fixed effect, pooled, and mean-group) to allow for various degrees of heterogeneity in the long-run parameters and in their short-run dynamics. Their findings suggest a stable relationship between output and energy consumption and a bi-directional long- and short-run causality between energy consumption and output.

Nadeem and Munir (2016) investigated the relationship between energy consumption and economic growth on a disaggregated basis, using annual data from 1972 to 2014. They used the autoregressive distributed lag (ARDL) bound testing approach and found a long-run relationship between economic growth and the disaggregated components of energy (aggregate and disaggregate oil, coal, gas and electricity consumption in different sectors). Bayar and Özel (2014) examined the relationship between economic growth and electricity consumption in the emerging economies over the period, 1970-2011, using Pedroni, Kao and Johansen co-integration and granger causality tests. They reported that electricity consumption had a positive impact on economic growth. They also observed a bi-directional causality between growth and electricity consumption. Mahmoudinia et al. (2013) explored the inter-temporal causal relationship among economic growth, energy consumption, electricity consumption and price during 1973-2006.They employed the ARDL bounds testing approach which exhibited a long run co-integration among all the variables. The results also showed a unidirectional casual effect of energy and electricity consumption on economic growth with a negative impact on economic growth in long run.

Chaudhry et al. (2012) studied the relationship between energy consumption and economic growth for Pakistan based on annual data for the period, 1972-2012.Their results show that electricity consumption positively affects economic growth, while oil consumption adversely affects economic growth largely because of its high import volume. Sama and Tah (2016) examined the effect of energy consumption (petroleum and electricity) on economic growth in Cameroon over the period, 1980-2014. Using the generalised method of moments technique, the results showed a positive relationship between petroleum consumption, electricity consumption and GDP. To et al. (2013) applied ARDL bound test to time series data from 1970 to 2011 to explore the causal relationship between energy consumption and economic growth in Australia. They formulated a production function to synthesize the models of neoclassical and endogenous growth and ecological economics viewpoint. They found no causality between energy consumption and economic growth, which essentially corroborates the 'neutrality' hypothesis.

Matei (2013) examined the energy consumption-economic growth nexus for 26 OECD countries during 1971-2013, using panel data technique. The study found that increases in real per capita GDP had a positive and statistically significant effect on per capita energy consumption, and vice-versa. Specifically, in the long-term, a 1.0% increase in real per capita GDP raises per capita energy consumption by about 0.3%, while a 1.0% increase in per capita energy use increases the real per capita GDP by about 1.3%. Using the same technique, Matei (2016) undertook a similar study in 7 Black Sea countries during 1990-2012 and found the same results: a 1.0% increase in real per capita GDP increases per capita energy consumption by over 0.60%. Also, a 1.0% increase in per capita energy use increases the real per capita GDP by a little over 1.0%, implying that the impact of real GDP on energy consumption was less important than vice versa. Dedeoglu and Piskin (2014) employed a dynamic panel framework to examine the causal relationship between energy consumption and real GDP per capita for the 15 former Soviet Union countries during 1992-2009. Their results confirmed a unidirectional causality running from energy consumption to real GDP per capita in the long-run but not in the short-run. The authors, however, observed a bidirectional relationship for oil and natural gas importing countries.

2.3. The Nigerian Context of the Empirical Literature

Ebohon (1996) conducted a two-country (Nigeria and Tanzania) examination of the causal directions between energy consumption and economic growth. There was evidence of a simultaneous causal relationship between energy and economic growth for both countries. The author then concluded that unless the existing energy supply constraints in the two countries and others in the Sub-Saharan Africa region (SSA) were seriously tackled, economic growth and development would remain elusive to the countries. Unfortunately, the same energy scenario observed more than 20 years ago is still persisting in SSA and these economies have continued to wallow in the dark side of civilization, while apparently ignoring the key role that energy plays in economic growth and development. Gbadebo and Okonkwo (2009) investigated the relationship between energy consumption and economic growth in Nigeria from 1970 to 2005, applying the co-integration and error correction model (ECM). The results confirmed the existence of a positive relationship between energy consumption and economic growth. Orhewere and Henry (2011) found unidirectional causality from electricity consumption and gas consumption to GDP both in the short-run and long-run; unidirectional causality from oil consumption to GDP in the long-run, but no causality in either direction between oil consumption and GDP in the short-run.

Akinwale et al. (2013) investigated the relationship between electricity consumption and real GDP growth in Nigeria, using the vector autoregression (VAR) model and ECM. They reported a unidirectional causality from real GDP to electricity consumption without a feedback effect. However, Ogundipe and Ayomide (2013) using the VECM and granger causality test on annual data from 1980-2008 observed bi-directional causal relationship between electricity consumption and economic growth. Onakoya et al. (2013) used the co-integration and ordinary least squares (OLS) techniques to evaluate the causal nexus between energy consumption and Nigeria's economic growth during the period, 1975 and 2010. The results showed that, in the long run, total energy consumption had a similar movement with economic growth except for coal consumption. Also, the authors found that petroleum, electricity and the aggregate energy consumption had significant and positive relationship with economic growth, while displaying a negative relationship with gas consumption.

Akomolafe and Danladi (2014) used the vector error correction (VEC) model and granger causality test and found a unidirectional causality from electricity consumption to real GDP. The long run estimates affirm that electricity consumption is positively related to real GDP in the long run. Okoligwe and Ihugba (2014) employed the Johansen Cointegration test, error correction model (ECM) and Granger causality test to evaluate the relationship between energy consumption and economic growth in Nigeria from 1971 to 2012. They found unidirectional causality from energy consumption to economic growth. Also, Mustapha and Fagge (2015) examined the causal relationship between energy consumption and economic growth in Nigeria, using annual data from 1980 to 2011 with the cointegration and VEC model and granger causality test. They did not find any causality, instead, their variance decomposition showed capital and labour as more important in increasing output growth than energy consumption. Iyke (2015) reported causality running from electricity consumption to economic growth in both the short- and long-run. Other Nigerian related studies on this subject matter include Aworinde (2002), Richard (2012), and Ouedraogo (2013).

The unanimous conclusion from the above Nigerian studies is that energy consumption has a positive influence on economic growth. Not only that, these studies confirm the hypothesis that energy supply/consumption promotes economic growth. However, these conclusions are yet to be tested under the recently developed Nonlinear ARDL methodology. In other words, the dynamics of this relationship may have been mis-specified. For instance, the study by Alimi (2016) shows that the relationship between macroeconomic volatility and economic growth is not linear; while Romero-Meza et al. (2014) found evidence of nonlinearity in the relationship between the oil sector and industrial production in the United States. Subjecting the energy-growth relationship to alternative model specifications, therefore, underlines one of the key contributions of this study to the literature. Clearly, the energy-growth nexus is both intuitively appealing and attests to the positive externalities of energy, especially electricity, on economic growth and development. Thus, policies aimed at exploiting this nexus must be based on more comprehensive evidence, which the present study provides.

3. METHODOLOGY AND MODEL SPECIFICATION

To analyse the asymmetric response of real GDP following changes in energy consumption, we use the asymmetric equilibrium or cointegrating relationship of the form:

$$Y_t = \theta^+ X_t^+ + \theta^- X_t^- + \varepsilon_t \quad (1)$$

where: Y_t is an integrated of order one variable, I(1),which denotes the logged representation of real GDP; and X_t is the regressor or independent variable, that is, logged representation of energy consumption, which we decompose as follows:

$$X_t = X_0 + X_t^+ + X_t^- \quad (2)$$

Where: $X_t^+ = \sum_{j=1}^{t} \max(\Delta X_j, 0)$ and $X_t^- = \sum_{j=1}^{t} \max(\Delta X_j, 0)$ are positive and negative partial sum processes used to account for increases and decreases in energy consumption X_t, while X_0 is a threshold value that we assume to be zero in line with the literature established in Shin et al. (2013). Δ denotes the first difference operator, while θ^+ and θ^- capture the asymmetric cointegrating or long-run coefficients. Our initial simulations with the regressor show that decomposing it as shown in equation (2) yields approximately 60:40 split of observations in favour of increases in energy consumption regime, which is consistent with Greenwood-Nimmo and Shin (2013). This means that we do not have to worry about estimation bias that may result from large differences in the regime probabilities. Equation (1) can then be expressed as a level form nonlinear autoregressive distributed lag model of order p and q, that is NARDL(p,q), as follows:

$$Y_t = \sum_{j=1}^{p} \phi Y_{t-j} + \sum_{j=0}^{q} (\theta_j^+ X_{t-j}^+ + \theta_j^- X_{t-j}^-) + \varepsilon_t \quad (3)$$

Where: the autoregressive coefficients are rooted in Φ_j; the asymmetric distributed lag coefficients are embedded in , $_j^+$ and , $_j^-$; while ε_t is the independently and identically distributed white noise process with zero mean and constant variance, σ_ε^2. This study adopts the general-to-specific lag selection approach beginning with a maximum lag length of 4 quarters (i.e., 1 year) and applying with a unidirectional 5% decision rule so that $p_{maximum} = 4$ and $q_{maximum} = 4$. This lag selection approach corresponds with the established literature such as Greenwood-Nimmo and Shin (2013). In fact, this approach ensures that neither the functional form of the equilibrium relationship nor the model dynamics is arbitrarily mis-specified.

Since this study is interested in analysing both long-run and short-run asymmetries in the energy-growth relationship as well as the speed of adjustment in short-run disequilibrium, equation (3) is now expressed in its error correction form as follows:

$$\Delta Y_t = \begin{matrix} \rho Y_{t-1} + \theta^+ X_{t-1}^+ + \theta^- X_{t-1}^- + \\ \sum_{j=1}^{p-1} \phi_j \Delta Y_{t-1} + \sum_{j=0}^{q-1} (\pi_j^+ \Delta X_{t-j}^+ + \pi_j^- \Delta X_{t-j}^-) + \varepsilon_t \end{matrix} \quad (4)$$

Where: ρ denotes the speed of adjustment; while the asymmetric long-run parameters are denoted by $\beta^+ = -\frac{\theta^+}{\rho}$ and $\beta^- = -\frac{\theta^-}{\rho}$.

The NARDL model in equation (4) is particularly appealing for two main reasons. First, it allows for the testing of the hypotheses of both long-run and short-run asymmetries. Second, it adjusts perfectly for potential weak endogeneity of nonstationary regressors through the model's lag structure. The second point is quite important because the level of economic activities may be an important determinant of energy consumption so that both variables are somewhat endogenous. Following the estimation of equation (4), this study evaluates the two asymmetries of interest, namely long-run and short-run asymmetries, using the standard Wald IJEEP 8902 ogbuabor oke and in the case of short-run asymmetry, we evaluate the null hypothesis of no additive asymmetry using $H_0 : \sum_{j=0}^{q-1} \pi_j^+ = \sum_{j=0}^{q-1} \pi_j^-$.

At this point, it is important to highlight some of the additional features of the NARDL model in equation (4) which have made it the preferred model for this study. These features include: (i) it is linear in parameters and easily estimable by OLS; (ii) it accommodates combinations of both I(0) and I(1) variables; and (iii) the null hypothesis of no equilibrium relationship between the levels of the variables is easily tested using the bounds-testing approach of Pesaran et al. (2001) (henceforth PSS) as well as the t_{BDM}-Statistic of Banerjee et al. (1998), and the conclusions thus obtained remain valid regardless of whether the explanatory variables are I(0), I(1) or mutually cointegrated (Ogbuabor et al., 2018).

As a robustness check, we also report the result from ARDL-ECM, which presupposes that the relationship is rather linear. Thus, following Borenstein et al. (1997), we assume a simple linear long-run relationship between real GDP (Y_t) and energy consumption (X_t) of the form:

$$Y_t = \alpha + \lambda X_t + \varepsilon_t \tag{5}$$

Where ε_t is the i.i.d. error term. The static cointegrating model in (5) is generally associated with two main challenges, namely: the residual usually show significant serial correlation and X_t is not usually exogenous with respect to ε_t. The last point is particularly important since the level of economic activities may be an important determinant of energy consumption. In this case, the OLS estimator of the cointegrating parameter is poorly determined in finite samples, suggesting that the problems of serial correlation and endogeneity of the regressor must be addressed. To address these twin problems, we adopt the approach of augmenting an ARDL specification with adequate number of lagged changes in the dependent and the independent variables. This approach is super-consistent in finite samples and generally performs better than the static model in (5), and the parameters of the estimated model have obvious economic interpretation since the variables are logged prior to estimation. To do this, we specify the following ARDL (p,q) model in its error correction form (ECM):

$$\Delta Y_t = \alpha_0 + \alpha Y_{t\text{-}1} + \theta X_{t\text{-}1} + \sum\nolimits_{j=1}^{p} \lambda_j \Delta Y_{t\text{-}j} + \sum\nolimits_{j=0}^{q} \gamma_j \Delta X_{t\text{-}j} + \mu_t \tag{6}$$

Where: the orders of the ARDL model, p and q, are selected using Akaike Information Criteria (AIC); λ and γ embed the short-run dynamics; α and θ embed the long-run relationship; α_0 is the constant; μ_t is i.i.d. error term; and is the first difference operator. Equation (6) recognizes that the response of real GDP to changes in energy consumption is not instantaneous but dynamic. Consistent with Pesaran and Shin (1999) and Pesaran et al. (2001), the finite sample performance of equation (6) is much superior to that of the static cointegrating regression in equation (5). However, estimation of (6) proceeds in three steps. First, we use the bounds testing procedure of PSS to check if the variables are cointegrated. If cointegration is established, then the second step involves the estimation of the long-run relationship, which is given by:

$$Y_t = \alpha_0 + \sum\nolimits_{j=1}^{p} \text{»} Y_{t\text{-}j} + \sum\nolimits_{j=0}^{q} {}^{3}{}_{j} X_{t\text{-}j} + \mu_t \tag{7}$$

The last step involves the estimation of the short-run dynamics, which is expressed as:

$$\Delta Y_t = \alpha_0 + \rho ECM_{t-1} + \sum\nolimits_{j=1}^{p} \lambda_j \Delta Y_{t\text{-}j} + \sum\nolimits_{j=0}^{q} \gamma_j \Delta X_{t\text{-}j} + \mu_t \tag{8}$$

Where: *ECM* is the error correction term embedding the long-run relationship; ρ is the speed of adjustment; λ and γ are the short-run parameters; while μ_t is well behaved.

In line with the established literature, this study also conducted Granger causality test on energy consumption and economic growth in Nigeria. The issue of causality relationship is useful in analysing how an economic time series can be used to forecast another. Thus, a variable X_t is said to Granger-cause another series Y_t, if given the past of Y_t, past values of X_t can help forecast Y_t. According to Gujarati and Porter (2009), the Granger causality test assumes that the information relevant to the prediction of the respective variables in a given model is contained solely in the time series data of these variables. Generally, it is important to note that since the future cannot predict the past, if variable X_t granger-causes variable Y_t, then changes in X_t should precede changes in Y_t. Therefore, in a regression of Y_t on other variables (including its own past values), if we include past or lagged values of X_t and it significantly improves the prediction of Y_t, then we can say that X_t granger-causes Y_t. A similar definition applies if Y_t granger-causes X_t. Thus, the model may be expressed as follows:

$$Y_t = \sum\nolimits_{i=1}^{n} \alpha_i X_{t-i} + \sum\nolimits_{i=1}^{n} \beta_j Y_{t-i} + \mu_{it} \tag{9}$$

$$Y_t = \sum\nolimits_{i=1}^{n} \lambda_i X_{t-i} + \sum\nolimits_{i=1}^{n} \delta_j Y_{t-i} + \mu_{2t} \tag{10}$$

Where: $\alpha_i, \beta_j, \lambda_i, \delta j$ are the parameters to be estimated, and it is assumed that the disturbances μ_{1t} and μ_{2t} are uncorrelated. The first differences of the variables are used in the estimation of (9) and (10) if the variables are found to be nonstationary but cointegrated.

3.1. The Data

The study data consists of 72 quarterly observations from 1999Q1 to 2016Q4 on both real GDP (at constant 2010 prices) and energy consumption (measured as electricity consumption in megawatts per hour). The data were obtained from the National Bureau of Statistics and the CBN database, respectively. This study period is chosen to ensure that our results incorporate recent developments in these variables, subject to data availability. Following the literature, such as Greenwood-Nimmo and Shin (2013) and Ogbuabor et al. (2018), we transformed the data by indexing it to 2010 base year (that is, 2010Y = 100) and logged it prior to estimation. These transformations were performed to enhance the robustness of the estimates and to ensure that the results retain obvious economic interpretations.

Figure 1 presents the time series plots of the data, using the indexed representation of the data before it was logged for estimation. Some salient facts are discernible from this figure. One, apart from the 2008-2009 global financial crisis period during which output dipped drastically around 2009Q4, real GDP and energy consumption generally tend to comove in an upward direction, suggesting that both variables track themselves closely. This contrasts with the hypothesized asymmetric relationship advanced in our baseline nonlinear (asymmetric) ARDL model of equation (4). The close co-movement noticed in Figure 1 signifies the existence of symmetric economic growth-energy consumption relationship, thereby reflecting the fact that energy consumption is an important growth driver in the economy. Two, the relatively close co-movement between real GDP and energy consumption also suggests the existence of a stable long-run relationship between them. As part of our empirical analysis, we verify the existence of this relationship using the bounds-testing procedure of Pesaran et al. (2001) and thet_{BDM}-Statistic of Banerjee et al. (1998).

4. EMPIRICAL RESULTS

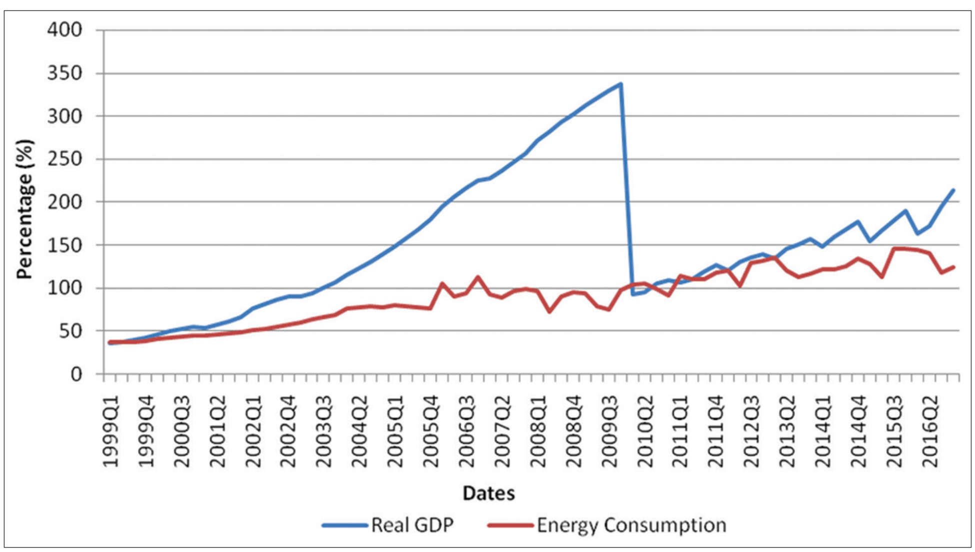
The starting point of our empirical analysis is the examination of the time series properties of the data. First, we tested for unit roots in each of the logged real GDP and energy consumption series, using the Augmented Dickey-Fuller (ADF) and Phillips-Perron unit root tests, controlling for both intercept and trend in the test equations since both series clearly displayed an overall upward trend in Figure 1. The results are presented in Table 1. We find that all the series are I(1) at the 5% level. This is consistent with the assumptions of both NARDL and ARDL-ECM specifications. Additionally, using the bounds-testing approach of PSS and the t_{BDM}-statistics of Banerjee et al. (1998), we confirm the existence of a stable long-run relationship between the series.

4.1. Nonlinear ARDL Estimation Results

The nonlinear autoregressive distributed lag (NARDL) model estimation results are shown in Table 2. Panel 1 depicts the estimated coefficients without using the robust standard errors, while Panel 2 reports the same coefficients after using the Newey-West autocorrelation heteroskedasticity corrected (HAC) standard errors. The use of robust standard errors in Panel 2 became necessary since the Breusch-Pagan-Godfrey heteroskedasticity test in Panel 1 shows that heteroskedasticity is a problem even at the 1% level.

The results in Table 2 indicate a very low speed of adjustment, which is 18%. This sluggish speed of adjustment suggests that contrary to economic expectation, economic growth is not responding rapidly to the dynamics of energy consumption in Nigeria. This finding is quite interesting bearing in mind the results of the other estimated coefficients. We find that after solving the problem of heterosckedasticity in Panel 2, none of the estimated coefficients is statistically significant, even at the 10% level. This means that the role of energy consumption in driving growth in Nigeria remained muted both in the short-run and long-run. However, the results indicate that energy consumption is positively related to economic growth in the long-run, while both variables are negatively related in the short-run. This is consistent with Akomolafe and Danladi (2014) and Gbadebo and Okonkwo (2009), which also found a positive relationship between energy consumption and growth in the long-run. The symmetry tests in Panel 2 also indicate the absence of both long-run and short-run asymmetry at the conventional 5% level, which is consistent with Trabelsi (2017) that found similar symmetric relationship between the oil sector and the agricultures and food sector in Saudi Arabia. However, the results overwhelmingly indicate that there is a stable long-run relationship between economic growth and energy consumption at the 5% level. This is clearly visible from the reported cointegration tests based on the PSS bounds testing approach as well as the t_{BDM}-statistic of Banerjee et al. (1998). At this point, our results indicate that even though energy consumption and economic growth have a stable equilibrium relationship, the role of energy consumption as a driver of growth remains unimportant both in the long-run and short-run.

Figure 1: Time series plots of the data



Source: Authors. These plots are based on the indexed representations of the data before they were logged for estimation

Table 1: Unit root test results

Variables	ADF test stat at level	5% critical values	ADF test stat. at 1st diff.	5% critical values	Order of integration
Real GDP	−1.932153	−3.474363	−8.219089	−3.475305	I(1)
Energy consumption	−3.179600	−3.474363	−9.285235	−3.476275	I(1)
Variables	**PP test stat. at level**	**5% critical values**	**PP test stat. at 1st diff.**	**5% critical values**	**Order of integration**
Real GDP	−1.943535	−3.474363	−8.219588	−3.475305	I(1)
Energy consumption	−2.797096	−3.474363	−28.88856	−3.475305	I(1)

Source: Authors. ADF and PP tests denote augmented dickey-fuller and Phillips-Perron unit root tests

Table 2: Nonlinear ARDL estimation results

Estimated coefficients	Panel 1: Without robust standard errors	Panel 2: With Newey-West HAC standard errors
ρ	−0.18***	−0.18
β^{+}	1.97***	1.97
β^{-}	2.83***	2.83
$\sum_{j=1}^{q-1}\pi_j^{+}$	−1.26***	−1.26
$\sum_{j=1}^{q-1}\pi_j^{-}$	−0.90**	−0.90
Symmetry Tests		
$H_0{=}\beta^{+}{=}\beta^{-}$	8.16***	2.78*
$H_0 = \sum_{j=1}^{q-1}\pi_j^{+} = \sum_{j=1}^{q-1}\pi_j^{-}$	0.94	0.74
Diagnostics		
F_{PSS}	4.96**	4.96**
t_{BDM}	−3.47**	−3.47**
BG test (NR^2) autocorrelation test	1.05	-
BPG heteroskedasticity test	16.03***	-
$\bar{R}^2$	0.31	0.31

Source: Authors. The notation for the estimated coefficients relates to the NARDL model of equation (4). The reported symmetry tests are standard Wald tests. The BG Test is the Breusch–Godfrey serial correlation test, while the BPG test is the standard Breusch-Pagan-Godfrey Heteroskedasticity test. The relevant k=1 critical values reported by PSS for the t_{BDM} statistic are −2.91, −3.22, and −3.82 at the 10%, 5% and 1% levels. The equivalent critical values for the F_{PSS} statistic are 4.14, 4.85 and 6.36. *denotes Significance at the 10% level; ** denotes Significance at the 5% level; while *** denotes Significance at the 1% level

Table 3: PSS bounds test results

Test statistic	Value	K	Level of significance (%)	Critical value bounds	
				I(0)	I(1)
F-statistic	6.719152	2	10	3.17	4.14
	6.719152	2	5	3.79	4.85
	6.719152	2	1	5.15	6.36

Source: Authors

The above finding is consistent with the dynamics of the Nigerian economy and anecdotal evidence of electric supply and demand in Nigeria. For instance, studies such as Akomolafe and Danladi (2014), Ogundipe and Ayomide (2013), among others, document that the demand for electricity in Nigeria is more than the supply, and that less than 40% of the population has access to electricity. These studies further explain that the electricity sector in Nigeria suffers from high energy losses (ranging between 30% and 35%) due mainly to ageing facilities, loss of equipment to vandals, corrupt investment and management of public enterprises in Nigeria, illegal access to transmission lines, and hydrological challenges during dry season. The results of these energy losses is that economic agents in Nigeria have continued to suffer from unreliable energy supply which, in turn, imposes economic burden on businesses, the public sector and the economy. Epileptic power supply discourages the deployment of modern technologies that are unsupported by power outages or low voltage. These facts accord with the muted role of energy consumption established in this study.

An important question then is: Are these results robust to the ARDL-ECM specification? Put differently, is it possible that the hypothesized relationship is linear rather than nonlinear? To clear this suspicion, we subject the above findings to a robustness check using the ARDL-ECM specification in equation (6). The PSS bounds test results associated with this specification are presented in Table 3. As before, the results indicate that at the conventional 5% level, there is a stable equilibrium relationship between energy consumption and economic growth in Nigeria, with F-statistic of 6.72 being greater than the upper bound of 4.85.

Following the establishment of equilibrium relationship between the variables, we estimated the long-run relationship of equation (7) and the results are shown in Table 4. The results indicate that both increases and decreases in energy consumption exact cumulative positive impact on economic growth in Nigeria. However, the impacts of increases and decreases in energy consumption on economic growth remained muted in all cases after the standard errors of the estimates were corrected for the problem of heteroskedasticity. These results are qualitatively the same as those of the nonlinear ARDL model. Indeed, we have established that regardless of the specification adopted, the role of energy consumption as a driver of growth in Nigeria remains unimportant, notwithstanding the stable equilibrium relationship existing between these variables.

Table 5 reports the short-run dynamics, following equation (8). The results are consistent with our earlier findings, which indicate that the role of energy consumption as a driver of growth is unimportant in the short-run. Notice that the error correction term (ECM) in Table 5 is well behaved, that is, it has a negative sign and it is significant at least at the 10% level.

As part of this empirical analysis and following the bulk of the empirical literature, we subjected the variables in this study to Granger causality analysis. The results are reported in Table 6. Panel 1 decomposes energy consumption into positive and negative partial sum processes, while Panel 2 treats energy consumption as a regressor. From Panel 1, we find that there is a unidirectional causality running from increases in energy consumption to economic growth at the 5% level; and from Panel 2, we also find a unidirectional causality running from energy consumption to economic growth. Both panels indicate that increase in energy consumption is important towards increased economic growth in Nigeria. This finding is particularly interesting

Table 4: ARDL-ECM long-run results (ARDL[1,2,3]) (dependent variable=LRGDP)

Variables	Coefficients	Panel 1: Without robust standard errors			Panel 2: With HAC standard errors		
		Std. errors	t-stat.	P-values	Robust std. errors	t-stat	P-value
LRDGP(-1)	0.7593	0.0581	13.0773	0.0000	0.1369	5.5444	0.0000
LECONS_P	-0.1014	0.2927	−0.3465	0.7302	0.2244	−0.4520	0.6529
LECONS_P(-1)	-0.7125	0.3629	−1.9635	0.0542	0.5910	-1.2056	0.2327
LECONS_P(-2)	1.2031	0.2880	4.1771	0.0001	0.8663	1.3889	0.1700
LECONS_N	-0.6308	0.3426	−1.8409	0.0706	0.4153	−1.5190	0.1340
LECONS_N(-1)	0.5084	0.4787	1.0621	0.2924	0.4133	1.2302	0.2234
LECONS_N(-2)	-0.5683	0.4998	−1.1369	0.2601	0.5470	−1.0388	0.3030
LECONS_N(-3)	1.2606	0.4126	3.0550	0.0034	0.8941	1.4098	0.1638
CONSTANT	0.9961	0.2273	4.3830	0.0000	0.5292	1.8822	0.0647
Diagnostics:							
Adjusted R-squared	0.9275						
F-stat	109.6810						
Prob (F-stat.)	0.0000						
Prob (BG test)	0.8255						
Prob (BPG test)	0.0003						
Prob (Ramsey RESET test)	0.7996						

Source: Authors. LRGDP and LECONS denote logged real GDP and energy consumption, respectively. BG Test is the Breusch–Godfrey serial correlation test while BPG test is the Breusch-Pagan-Godfrey Heteroskedasticity test. The P-values for these tests are reported

Table 5: ARDL-ECM short-run dynamics (dependent variable=ΔLRGDP)

Variables	Coefficients	Std. errors	t-stat.	P-values
ΔLRDGP(-1)	0.7291	0.3880	1.8789	0.0653
ΔLECONS_P	−0.1278	0.2033	−0.6288	0.5320
ΔLECONS_P(-1)	−0.6949	0.6310	−1.1012	0.2754
ΔLECONS_P(-2)	1.1044	0.7178	1.5385	0.1294
ΔLECONS_N	−0.5810	0.4071	−1.4272	0.1589
ΔLECONS_N(−1)	0.5078	0.3388	1.4987	0.1394
ΔLECONS_N(−2)	-0.5336	0.6084	−0.8771	0.3841
ΔLECONS_N(−3)	1.3970	0.8763	1.5942	0.1163
ECM(−1)	−0.9307	0.4937	−1.8852	0.0644
CONSTANT	0.0120	0.0329	0.3659	0.7158
Diagnostics:				
Adjusted R-squared	0.2948			
F-stat.	4.1123			
Prob (F-stat.)	0.0004			

Source: Authors. Δ denotes the first difference operator. Other notations relating to equation (8) apply

Table 6: Granger causality test results

Panel 1: With increases and decreases in energy consumption

Null hypothesis:	Obs.	F-statistic	Prob.
ΔLECONS_N does not granger cause ΔLRGDP	70	0.90826	0.4083
ΔLRGDP does not granger cause ΔLECONS_N		2.93499	0.0602
ΔLECONS_P does not granger cause ΔLRGDP	70	4.85193	0.0109
ΔLRGDP does not granger cause ΔLECONS_P		1.57869	0.2141

Panel 2: Without decomposing energy consumption

Null hypothesis:	Obs.	F-statistic	Prob.
ΔLRGDP does not granger cause ΔLECONS	70	0.32704	0.7222
ΔLECONS does not granger cause ΔLRGDP		4.59179	0.0136

Δ and L denote the first difference and natural log operators, respectively

because it underlines the fact that Nigeria cannot attain high levels of sustainable growth without improved and stable energy supply. This finding is also consistent with some of the studies in the literature, such as Orhewere and Henry (2011), Okoligwe and Ihugba (2014), and Akomolafe and Danladi (2014).

5. CONCLUSION AND POLICY IMPLICATIONS

This study investigated the relationship between energy consumption and economic growth in Nigeria from 1999Q1 to 2016Q4 based on alternative specifications. First, the study used the nonlinear ARDL (NARDL) model recently advanced by Shin, Yu and Greenwood-Nimmo and Shin (2013), which allows for the regressors to be decomposed into positive and negative partial sum processes so that the responses of the dependent variable to increases and decreases in the regressors can be modelled in a coherent way. Second, the study also used the ARDL-ECM specification of Pesaran et al. (2001) to verify if the presumed relationship is linear rather than nonlinear. Overall, we find that the role of energy consumption as a driver of growth remained negligible throughout, suggesting that a lot still needs to be done to ensure that the expected role of energy begins to manifest in the economy. The Granger causality tests revealed a unidirectional causality running from energy consumption to economic growth, indicating that Nigeria can attain high levels of sustainable growth with improved and stable energy supply. In other words, energy supply has the potential to impact tremendously on the performance of the Nigerian economy.

These findings constitute a wake-up call on governments and policymakers in Nigeria. It is also a wake-up call on other African economies, since they share a lot of structural similarities with Nigeria, especially ECOWAS member countries. Particularly, the findings that the role of energy in the growth process remained muted all through and that causality runs from energy to growth indicate that there is an urgent need to evolve and implement policies that will address the energy challenges of the Nigerian economy. This is particularly important since every sector of the economy depends on energy supply for its sustenance. For instance, most deaths in Nigeria and other developing countries in SSA may be attributed to electricity supply deficit. Almost all public hospitals operate under unreliable electricity supply. Equally, most schools (public and private alike) do not have regular electricity supply to power education and knowledge development. Health, education, and entrepreneurship can only flourish and contribute to higher economic growth under the condition of regular energy supply. Therefore, the nature and direction of causality between energy consumption and economic growth and development have important implications for policy analysis and prescription. Despite the historically acknowledged fundamental role of energy in economic transformation and development, which is a stylized fact in the developed and fast-developing societies, steady energy supply has remained a mirage at worst or a luxury at best in Nigeria and other SSA countries. This study therefore provides policy insights into the role of energy as a key driver of economic development and into the economic consequences of energy supply deficits in the economy.

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