GROWTH-LED ENERGY HYPOTHESIS IN NIGERIA: AN ASYMMETRIC INVESTIGATION

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Abstract

The main goal of this study is to contribute to the ongoing empirical discourse by considering the possibility of an asymmetric connection between economic growth and energy consumption in Nigeria. Applying the Non-linear Autoregressive Distributed Lag (NARDL) approach on annual data from the period 1971 to 2018, the findings suggest that there is a significant asymmetric effect of economic growth on energy consumption in the long-run using the bounds test. Furthermore, the effects of negative and positive shocks to economic growth vary in both the long-run and short-run. More specifically, a positive shock to economic growth affect energy consumption negatively in the short-run but positively in the long-run while a negative shock to economic growth has a significant positive effect on energy consumption in the short-run and insignificant positive effect in the long-run. The result of this study also indicates that foreign direct investment has a negative effect on energy consumption in both the long and short-run, while capital has a contradictory effect on energy consumption in both periods. This study concludes that economic growth has a non-linear effect on energy consumption in both the short and long-run.

Keywords: Economic growth; Energy Consumption; Non-Linear Auto-regressive Distributed Lag; Nigeria

JEL Classification: C52; Q43

Introduction

Central to achieving sustainable and inclusive economic growth is the universal increment in affordable and clean energy through new job opportunities. That is, while energy is a fundamental input required for production and development globally, economic growth, which measures increases in a country's capacity to produce goods and services, is among the determining factors of energy consumption. The global per capita energy use over the years shows an upward trend, and evidence from low to high-income countries (Figure 1) suggests that per capita energy use increases with per capita GDP given that poorer countries use less energy per person compared with richer countries.

Nigeria has tried to diversify the economy from a highly agrarian economy in the 1960s to an industrialised one given her pool of non-renewable and renewable energy resource. By implication, the consumption of energy has been on the increase because of industrialization, globalization, and population growth since energy supports manufacturing, agricultural, education and health sector among others. The country has also been regarded as an economy with high potential for growth, given her large amount of natural resource endowments, active labour force and an increasing manufacturing sector which reinforces an increasing demand in energy consumption. Despite this, energy consumption in Nigeria is comparatively very low with over 40% lacking access to electricity (The World Bank, 2018) while a substantial amount of energy is flared during flaring offshore crude oil extraction which amounts to waste.

The debate surrounding the nexus between energy consumption and economic growth has been ongoing for decades following the Harrod (1939) – Domar (1946) growth theory, and Solow - Swan (1956) model, through to the endogenous growth theories where technological progress is considered paramount to economic activities (Lee, Chang & Chen, 2008). Empirical evidence provided by Kraft and Kraft (1978), Huang, Hwang, and Yang (2008), Lee et al., (2008), Adom (2011), Ouedraogo (2013), and Nayan, Kadir, Ahmad, and Abdulla (2013) amongst others suggest the existence of a one-way causal relationship running from growth to the consumption of energy in the United States, high and middle-income countries, 18 developing countries, Ghana, the ECOWAS region (Nigeria inclusive), and 23 US countries respectively. This implies that increases in these country's output increase aggregate demand and the consumption of energy-intensive goods and services as the economy move from one stage of development to another. Despite the validation of the growth-led energy hypothesis in many countries, the focus of most Nigerian studies (Akinlo, 2008; Iyke, 2015; Okorie & Sylvester, 2016) has been the direction of causality between electricity consumption and economic growth. Besides, other studies (Orhewere & Henry, 2011; Muse, 2014; Ekeocha, Penzin, & Ogbuabor, 2020) that set out to evaluate the relationship between economic growth and energy consumption simply made use of a fraction of energy consumption (oil consumption or electricity consumption).

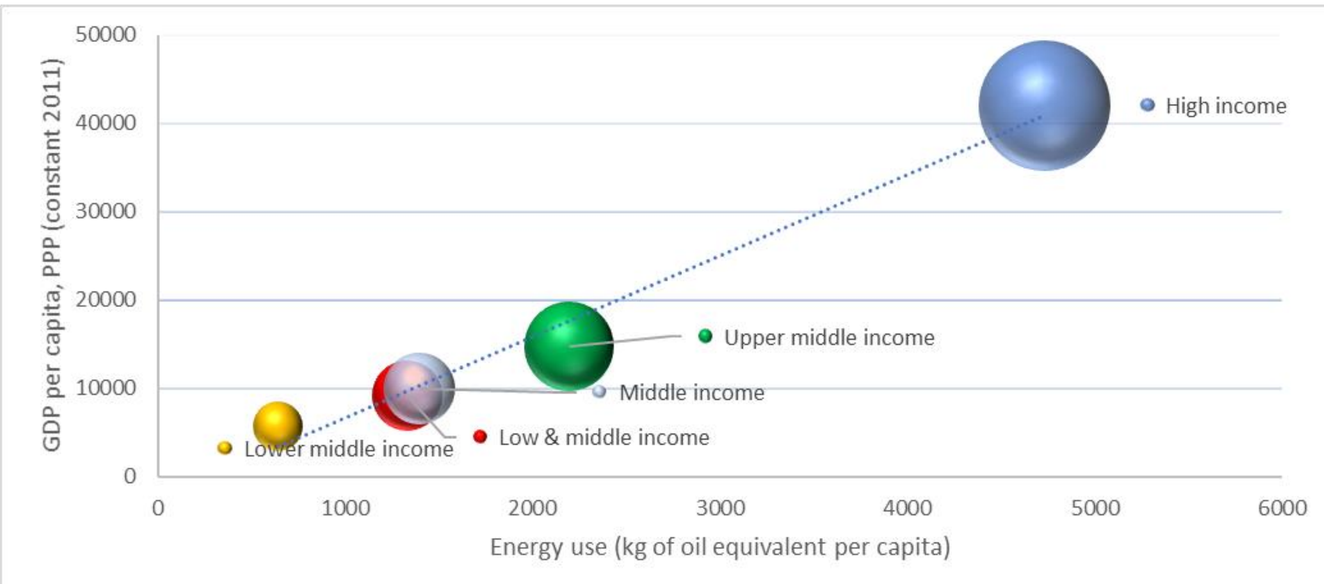

Figure 1: GDP-Energy Relationship in low and high-income countries using per capita energy use and GDP per capita of 2014. Bubbles are proportional to total energy consumption.
Source: The World Bank (2020)

Although there is no explicit theoretical underpinning suggesting an asymmetric relationship between these variables, there are a number of the recent empirical literature (Bildirici & Ozaksoy, 2017; Noh & Masih, 2017; Shahbaz, Hoang, Van, Mahalik & Roubaud, 2017; Baz et al., 2019) suggesting the existence of a non-linear relationship between them. These are engendered by hidden and unanticipated events, such as economical, ecological, political, and financial changes. Moreover, both series are non-stationary at level, strengthening the argument for investigating the co-integrating non-linear relationship rather than the symmetry and linear approach. Based on the foregoing, it is imperative to validate or invalidate the growth-led energy hypothesis in Nigeria giving consideration to the possibility of a non-linear relationship in contrast to the linearity assumption of other Nigerian studies. This is important because when the association between energy consumption and economic growth is non-linear, then the use of the linear estimates is considered inappropriate as it may lead to biased estimates and wrong policy implications. This study is, therefore, an extension of previous studies which investigates the economic growth and energy consumption nexus and it is sectioned into five. The first section of this study gives a general background to the study. The second part contains the literature review while the third part focuses on the methodology, which includes model specification. The fourth and fifth sections entail the discussion of findings and conclusion respectively.

Literature review

It is no gainsaying that empirical literature on the nexus between economic growth and energy consumption has been topical for decades, and the findings have been inconsistent globally. Following the pioneering study on this discourse by Kraft and Kraft (1978) which proposed that the consumption of energy is led by increases in the Gross National Product (GNP), various studies have emerged to buttress this view (Akarca & Long, 1980; Yu & Choi, 1985; Masih & Masih, 1997).

Concerning the issue of causality between these two variables, evidence from developed countries (Yildirim, Saraç, & Aslan, 2012) suggests that no form of causality exist between energy consumption when measured with hydro-electricity, total renewable energy, biomass, geothermal and biomass-wood-derived energy consumption and output having applied the bootstrap-corrected causality test and the Toda-Yamamoto approach. A similar study on 15 European countries conducted during the period 1990 and 2011 indicate a long-run nexus and a one-way causal relationship between real output and non-renewable energy consumption (Ucan, Aricioglu, & Yucel, 2014), meanwhile, a study by Can and Korkmaz (2019) found no long-run relationship between renewable energy consumption and economic growth.

Using a panel approach, Huang et al., (2007) employed the system GMM estimation technique in discussing the connection between economic growth and energy consumption among 82 countries. Their findings showed that economic growth has no causal link with energy consumption in low-income countries, it negatively affects the consumption of energy in high-income countries, but it positively affects it in middle-income countries. Similarly, Nayan et al., (2013) revisited the issue of economic growth and energy consumption among 23 countries using the GMM-system approach. Their findings like Lee and Chang (2007) showed that the consumption of energy has a minimal significant effect on output and there is a one-way causality between output and energy consumption. Focusing on 75 net energy importing countries, Esen and Bayrak (2017) found that the effect of energy consumption on economic growth is dynamic. Meanwhile, a study on 29 Organization for Economic Co-operation and Development (OECD) countries by Gozgor, Lau and Lu (2018) that was analysed through the panel quantile regression (PQR) estimations and an ARDL approach established that both non-renewable and renewable energy consumption is positively linked with an increased rate of economic growth.

Country specific studies, such as Paul and Bhattacharya (2004) suggest a two-way causal relationship between output and energy consumption in India. Meanwhile, Climent and Pardo (2007) considered different decoupling agents that influence the linkage between energy consumption and GDP in Spain. No long-run relationship was discovered between energy consumption and output; however, causality was discovered in the short-run after accounting for the influence of oil price and other variables. Also using the Granger causality test, evidence from Turkey (Erdal, Erdal, & Esengun, 2008) showed that output and energy consumption are cointegrated and that causality runs in both ways. Whereas, Herrerias, Joyeux, and Girardin (2013) who employed a panel co-integration technique in examining the nexus between economic growth and energy consumption in China found a long-run causal effect flowing from output to energy consumption.

Evidence from Africa, provided by Odhiambo (2009a) using both energy and per capita electricity consumption as proxies for energy consumption suggests the existence of a long-run connection between energy consumption and economic growth in Tanzania, while also showing a one-way causal effect flowing from energy consumption to economic growth. Whereas, Odhiambo (2009b) identified a distinct two-way causality between economic growth and energy consumption in South Africa. Using the Toda Yamamoto Granger causality test on data covering 1971 to 2008, Adom (2011) provided evidence supporting a one-way causal effect running from economic growth to energy consumption in Ghana.

Summarily, four major channels are connecting the studies on economic growth and energy consumption in the literature. These include the energy-led-growth hypothesis, growth-led energy hypothesis, feedback hypothesis, and neutrality hypothesis. Some studies that argued for the energy-led-growth hypothesis (Narayan & Popp, 2012; Aslan, Apergis & Yildirim, 2014; Gozgor, Lau & Lu, 2018) established that one major driver of economic growth is energy consumption, alongside labour and capital. Some focused on the growth-led energy hypothesis also known as the conservative hypothesis (Lee & Chang, 2007; Huang, Hwang, & Yang, 2008; Narayan, 2016; Kasman & Duman, 2015) which implies that a decrease in the consumption of energy may have very little effect on real GDP. Diversely, studies on the feedback hypothesis (Lean & Smyth, 2010; Esseghir & Khouni, 2014) establish a bi-directional causality between economic growth and energy consumption, meanwhile some others (Tang, 2008; Soytas & Sari, 2009; Amusa & Leshoro, 2013; Smiech & Papiez, 2014) established the neutrality hypothesis that suggests independence between economic growth and energy consumption. Conclusively, empirical evidence differs across developing and developed countries, variables employed and the methodological approach (Apergis & Tang, 2013; Stern, 2018).

Focusing on Nigeria, this study's major contribution to literature is the determination of the association between energy consumption and economic growth given the premise that the relationship between these variables differs across countries (Akinlo, 2008). This study also accounts for the effect of foreign direct investment because a bidirectional relationship has been established between energy consumption and foreign direct investment in Nigeria (Aremo & Ojeyinka, 2018). Besides, this study takes into account the potential asymmetric association between economic growth and energy consumption using an extended annual time series. This is essential because the negative or positive variations of the variables may not produce the same effect (Shahbaz et al., 2017).

Data and methodology

Data

This study employs annual data from 1971 to 2018 in investigating the asymmetric relationship between economic growth and energy consumption in Nigeria. A total of four variables namely, energy consumption proxied by total energy use (EGU) measured in kg of oil equivalent, gross domestic product (GDP) in constant 2010 US$, foreign direct investment (FDI), net inflow (percentage of GDP), and capital (CAP) proxied by gross fixed capital formation (constant 2010 US$) were utilized. The total energy consumption here includes the "energy from combustible renewables and waste - solid biomass and animal products, gas and liquid from biomass, and industrial and municipal waste" (World Development Indicators (WDI), 2020) and all the variables were also sourced from the WDI (2020), while their natural logarithm form was employed.

Method

Prior to the analysis of data, the unit root test was conducted for all the variables to ascertain whether they are stationary or not using the Augmented Dickey-Fuller (ADF), Phillip Peron (PP) and KPSS unit root tests after accounting for structural breaks. Since none of the variables of interest is integrated of order 2; the dependent variable energy consumption is stationary at the first difference *I(1)*; and, the bounds test for co-integration establishes a long-run relationship between these variables, the use of *ARDL is* justified. However, if the association between economic growth and energy consumption is non-linear, then the use of the linear *ARDL* may be considered inappropriate (Baz et al., 2019). In order to account for non-linear relationship and asymmetries caused by negative and positive shocks in economic growth, the *NARDL* introduced by Shin et al., (2014) is preferred.

This approach is robust to small sample size and it accommodates the test of hidden co-integration which would not be detected by the linear *ARDL* (Granger & Yoon, 2002; Rahman, Chongbo & Ahmad, 2019). Adapting the model of Nayan et al., (2013), the functional form of the model is specified in equation 1

$$EGU_t = f(GDP_t, FDI_t, CAP_t) \tag{1}$$

In this model, foreign direct investment (FDI) and capital have been introduced because they have been shown to affect energy consumption. Based on the empirical literature, their effect can either be positive or negative. That is, the transfer and inflow of energy-efficient technologies will reduce energy consumption whereas, investment (either from capital or FDI) can increase energy consumption through increases in manufacturing and industrialisation. Taking the natural logarithm of all the variables, the general association among the variables are presented in equation 2

$$\ln EGU_t = \delta_0 + \delta_1 \ln GDP_t + \delta_2 \ln FDI_t + \delta_3 \ln CAP_t + \mu_t \tag{2}$$

Where EGU represents energy consumption in the time t, GDP stands for the gross domestic product at a given time, FDI represents the foreign direct investment in period t, and CAP represents capital in the period t. The coefficients are represented by $\delta_1, \delta_2,$ and δ_3, the constant is denoted as δ_0, the error term is represented by μ_t and $\ln$ depicts the natural log.

Having established asymmetric co-integration through the bound test, the optimal lag length for this series was suggested by the Akaike Information Criteria (AIC) and Schwarz's Information Criteria (SIC). Then, GDP was decomposed into positive and negative variations in economic growth as captured below:

$$\ln GDP_t = \ln GDP_0 + \ln GDP_t^{+} + \ln GDP_t^{-} \tag{3}$$

Where, $\ln GDP_t^{+}$ and $\ln GDP_t^{-}$ are the partial summation of negative and positive differences in $\ln GDP_t$ and

$$\ln GDP^{+} = \sum_{j=1}^{m} \Delta \ln GDP_j^{+} = \sum_{j=1}^{m} \max(\Delta \ln GDP_j, 0) \tag{4}$$

$$\ln GDP^{-} = \sum_{j=1}^{m} \Delta \ln GDP_j^{-} = \sum_{j=1}^{m} \min(\Delta \ln GDP_j, 0)$$

Consequently, the asymmetric effect of economic growth on energy consumption in the study period is analysed given the error correction model specified in equation 5

$$\Delta \ln EGU_t = \delta_0 + \delta_1 \ln EGU_{t-1} + \delta_2^{+} l\, n\, GDP_{t-1}^{+} + \delta_3^{-} \ln GDP_{t-1}^{-} + \delta_4 \ln FDI_{t-1} + \delta_5 \ln CAP_{t-1} + \sum_{i=1}^{q} \beta_1 \Delta \ln EGU_{t-i} + \sum_{i=0}^{\rho} (\beta_2^{+} \Delta \ln GDP_{t-i}^{+} + \beta_3^{-} \Delta \ln GDP_{t-i}^{-}) + \sum_{i=1}^{\rho} \beta_4 \Delta \ln FDI_{t-i} + \sum_{i=1}^{\rho} \beta_5 \Delta \ln CAP_{t-i} + \mu_t \tag{5}$$

Where β_i implies short-run coefficients, δ_i represents the long-run coefficients, Δ denotes the first difference operator, and μ_t indicates the error term. The long-run coefficients show the time of reaction and the adjustment speed towards an equilibrium, whereas, the short-run coefficients indicate the instantaneous effect of economic growth, capital and foreign direct investment on energy consumption. Thereafter, the null-hypothesis for long-run asymmetry ($\delta = \delta^- = \delta^+$) and short-run asymmetry ($\beta = \beta^+ = \beta^-$) is analysed for economic growth using the Wald test.

The time plot of real GDP

Figures 2 through 4 depict the real GDP time plot as well as the cumulative function of the actual GDP negative and positive components. Figure 2, in fact, justifies the need for an asymmetric investigation since it reveals that, given the graph instability, real GDP will have an asymmetric effect on economic growth.

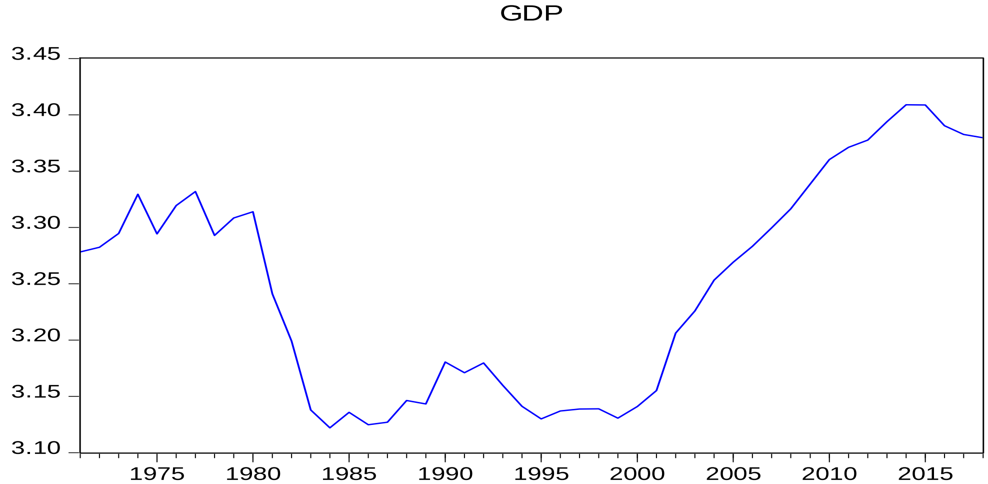

Figure 2: Real GDP in Nigeria (1971-2018)
Source: Authors' Computations

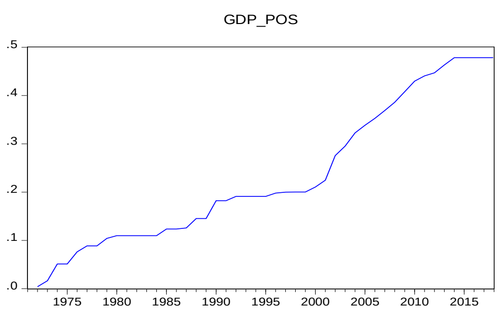

Figure 3: Cumulative function of positive component
Source: Authors' Computations

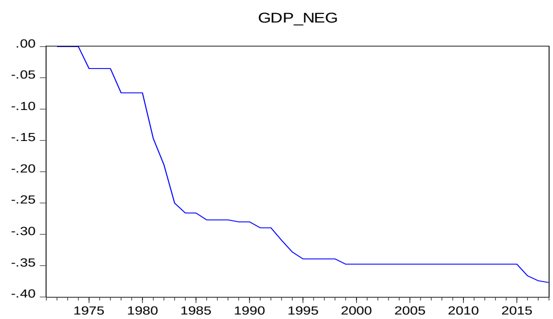

Figure 4: Cumulative function of negative components
Source: Authors' Computations

Descriptive statistics

Table 1 describes the statistical properties of the data involved. The data are summarized using the measure of location and dispersion as well as the distribution of the data. Furthermore, Table 1 indicates the maximum and minimum values of the variables. The maximum values of EGU, real GDP, FDI and CAP, as shown in the table, are 2.87, 3.33, 0.76 and 13.05, respectively, whereas the minimum values for the variables are 2.76, 3.12, -0.59 and 12.16, respectively. The data are found to be consistent as their average values of 2.83, 3.20, 0.11, and 12.61, respectively, fall within their minimum and maximum values. The standard deviation values for all variables indicate that the variables are no different from their mean values in any way. This is because the smaller the value of the standard deviation, the closer the data to its mean value.

Skewness can be used to describe a positive-skewed or a negative-skewed variable. EGU and FDI are negatively skewed, showing that, the left tails of their distributions are longer than the right tail, while each of real GDP and CAP has a right tail that is longer than the left tail, meaning that, both real GDP and CAP are positively skewed. For kurtosis, it can be used to describe the peakedness or flatness of any variable. The values obtained for kurtosis suggest that all the variables of interest are platykurtic, that is, they are flat-topped in relation to normal distribution since they have values that are less than 3.

Finally, the Jarque-Bera Statistics with insignificant values for all the variables means that all the variables are normally distributed since the null hypothesis of a normal distribution is accepted for all the variables.

Table 1: Summary of Statistics

Variable	LNEGU	LNGDP	LNFDI	LNCAP
Mean	2.83	3.20	0.12	12.61
Median	2.83	3.17	0.22	12.45
Maximum	2.87	3.33	0.76	13.05
Minimum	2.76	3.12	-0.59	12.16
Std. Dev.	0.03	0.07	0.36	0.29
Skewness	-0.86	0.56	-0.32	0.39
Kurtosis	2.91	1.67	2.36	1.61
Jarque-Bera (p-value)	4.12 (0.13)	4.18 (0.12)	1.14 (0.57)	3.51 (0.17)
Sum	93.30	105.66	3.85	415.98
Sum Sq. Dev.	0.03	0.17	4.08	2.63

Source: Authors' Computations

Empirical results

The aim of this study is to determine the asymmetric effects of economic growth on energy use in Nigeria by using the non-linear autoregressive distributed lag model (NARDL), taking into consideration the impacts of FDI and capital. This estimation technique is preferred because the model allows the possibility of asymmetric effects of negative and positive changes in controlled variables to be integrated on the outcome variable, as opposed to the normal ARDL where the possible impact of explanatory variables remains the same.

Unit root tests

When using the NARDL model, the order of integration is essential to ensure that none of the variables is integrated of order 2, that is, *I(2)*. This model is also appropriate where the variables are a mixture of *I(0)* and *I(1)*. The study employs Kwiatkowski-Phillips-Schmidt-Shin (KPSS), Phillips-Perron (PP) and Augmented Dickey-Fuller (ADF) unit root tests (with intercept only) to assess the order of integration. Most importantly, as both ADF and PP tests offer different integration orders the KPSS test is used to validate the order of integration. We reject the null non-stationarity hypothesis if the t-statistics from both the ADF and PP tests are higher than the critical values and we accept the null hypothesis if otherwise. This is not the case for the KPSS test as we accept the hypothesis of stationarity if its t-statistic is below the critical value. It is obvious from Table 2 that the variables are stationary at the first difference and none of the variables is integrated of order 2. Thus, this justifies the use of NARDL.

Table 2: Unit Root Tests without Structural Breaks

	ADF Test			PP Test			KPSS Test		
Variable	I(0)	I(1)	Status	I(0)	I(1)	Status	I(0)	I(1)	Status
LNEGU	-2.47	-5.71**	I(1)	-2.65*	-	I(0)	0.82	0.27**	I(1)
LNGDP$^+$	0.07	-2.91*	I(1)	-0.12	-5.62**	I(1)	-	-	-
LNGDP$^-$	-4.38**	-	I(0)	-2.47	-4.72**	I(1)	0.72	0.39**	I(1)
LNFDI	-1.66	-11.42**	I(1)	-2.68	-11.42**	I(1)	-	-	-
LNCAP	-0.91	-2.73*	I(1)	-0.34	-5.60**	I(1)	-	-	-
Critical Value	I(0)	I(1)		I(0)	I(1)		I(0)	I(1)	
5%	-2.93	-2.93		-2.93	-2.93		0.46	0.46	
10%	-2.60	-2.60		-2.60	-2.60		0.35	0.35	

Note: ** and * represent 5% and 10% significant levels.
Source: Authors' Computations

To account for structural breaks in the variables of interest, the study uses Perron (1989; 1997) test with structural change. In Table 3, energy use (LNEGU), positive shocks to economic growth (LNGDP$^+$), and capital (LNCAP) are stationary at the first difference, whereas negative shocks to economic growth (LNGDP$^-$) and foreign direct investment (LNFDI) are stationary at levels. The break dates were 1994, 2002, 1980, and 1988 for LNEGU, LNGDP$^+$, LNGDP$^-$, and LNFDI and LNCAP, respectively. During these periods, there were so many economic happenings in Nigeria that could account for substantial reductions in these variables. The events include an increase in the unemployment rate from 1.93% to 4.40% in 1980 (Project Writers, 2016); budget deficit of 2.2% (Central Bank of Nigeria, 1994); a drastic decline in government spending from 44% in 1979 to 17% in 1988 (countrystudies.us/Nigeria/52.htm) amongst others.

Table 3: Perron (1997) Unit Root Test with Structural Breaks

Variable	Break Date	I(0)	I(1)	Status
LNEGU	1994	-2.57	-6.89**	I(1)
LNGDP$^+$	2002	-4.82	-7.23**	I(1)
LNGDP$^-$	1980	-7.42**	-	I(0)
LNFDI	1988	-5.13*	-	I(0)
LNCAP	1988	-4.02	-5.85**	I(1)
Critical Value		I(0)	I(1)	
5%		-5.23	-5.23	
10%		-4.92	-4.92	

Note: ** and * represent 5% and 10% significant levels.
Source: Authors' Computations

Bounds testing

Before one can actually use the NARDL model, there is a need to check for the possibility of a long-run relationship among the interest variables. The conclusion from Table 4 shows that truly there is a long-run relationship among the variables because the F-statistic of 4.58 is greater than the lower and upper limits of 2.56 and 3.49, respectively. As a result, we can proceed with the NARDL model's short- and long-run form.

Table 4: Bound Testing

Ho: No long-run relationship among the variables			
F-statistic	Significant Level	Lower Boundary	Upper Boundary
4.58	5%	2.56	3.49

Source: Authors' Computations

Asymmetric effects of economic growth on energy consumption

Having identified the existence of a long-run relationship among the variables under consideration, we next examine the short- and long-run asymmetric effects of economic growth on energy consumption, as supported by the Wald test statistics and the error correction term, ECT (see Table 5). The selected optimum lag length is 4 based on the Akaike Information Criterion (AIC), and the order is given as NARDL (4, 4, 2, 3). The short-run dynamic estimates in Table 5 reveal that the previous energy consumption value would increase its present values significantly by 0.76 per cent. The finding ensures that energy use overtime is a stable measure of energy consumption. From the table, it is deduced that the short-run effects of economic growth on energy consumption are asymmetric, as its sum of positive coefficient estimates has a significant negative impact on energy consumption (Paul & Bhattacharya, 2004), whereas that of negative estimates exerts an insignificant positive effect on energy consumption (Huang, Hwang, & Yang, 2008; Tang, 2008; Soytas & Sari, 2009; Yildirim, Saraç, & Aslan, 2012, Amusa & Leshoro, 2013; Smiech & Papiez, 2014). Statistically, an increase (decrease) of 1 per cent in economic growth induces a decline (increase) of 1.76 per cent (0.17 per cent) in energy consumption. This means that increasing economic growth amounts to a high level of energy consumption while declining economic growth contributes to a decline in energy usage. But for the negative shocks to economic growth, the estimate is found to be insignificant. In other words, the analysis supports the hypotheses of conservativeness and neutrality by using the positive and negative shocks for short-run economic growth, respectively. The *ECT* of -1.57, which is significant with a correct sign, implies that about 157 per cent of short-run disequilibrium would be corrected for annually. This is an overreacting adjustment process. Also, the value of *ECT* greater than 1 implies an oscillatory convergence which suggests that the speed of adjustment fluctuates forward before settling to equilibrium.

Long-run asymmetrical impacts of economic growth on energy consumption occur in the same way. Table 5 shows that both positive and negative shocks to economic growth have a significant and positive long-run influence on energy consumption. Furthermore, an increase in the combined effect of positive and negative economic growth shifts by 1 per cent raises energy consumption by 1.28 and 0.10 per cents, respectively. The coefficient values suggest that energy consumption responds more rapidly than the negative shocks to the positive shocks of economic growth. The multiplier graph in Figure 4 defines this as well. This result is consistent with the studies of Lee and Chang (2007), Erdal and Esengun (2008), Huang, Hwang and Yang (2008), Odhiambo (2009b), Adom (2011), Joyeux, and Girardin (2013), Kasman and Duman (2015) and Narayan (2016) which supports the growth-led energy (conservative) hypothesis. This implies that increases in Nigeria's output potential will increase the energy consumed. It is obvious that the country's productive sector is growing day by day, thereby positively impacting energy usage in the different production processes. This shows that the impact of the positive and negative shocks on economic growth vary in terms of their coefficient values, indicating the existence of asymmetric long-run effects of economic growth.

On the control variables, foreign direct investment adversely influences energy consumption in both the short- and long-run with the same coefficient value, while capital has a positive effect and a negative effect on energy consumption in short- and long-run, respectively. The negative impact of capital on energy consumption in the short-run does not match the theoretical expectations in the long-run because investment from capital would accelerate the consumption of energy as a result of increasing manufacturing and industrialization. In particular, a 1 per cent rise in foreign direct investment decreases energy consumption in both the short-and long-run by 0.04 per cent. Meanwhile, energy consumption is increasing by 0.24 per cent and declining by 0.12 per cent in the short- and long-run, respectively, for a capital change of 1 per cent. Nevertheless, the positive effect of capital on energy consumption in the long-run supports the empirical evidence from Rafindadi and Mika'Ilu (2019).

From this study, it is well known, in terms of foreign direct investment, that any attempt to increase investment by foreigners would not increase energy consumption either in the short- or long-run. This is because most of these foreigners, as a result of energy failure in Nigeria, usually generate their means of energy supply by transferring energy-efficient technologies from their countries. This also provides the argument for a short-run negative relation between energy consumption and capital.

Table 5: NARDL estimation results

Panel A: Short-run dynamics coefficient estimates		
Variable	Coefficient	P-value
D(LNEGU(-1))	0.76**	0.02
D(LNGDP$^+$)	-1.76**	0.01
D(LNGDP$^-$)	0.17	0.79
D(LNFDI)	-0.04**	0.03
D(LNCAP)	0.24**	0.01
ECM(-1)	-1.59**	0.00
Panel B: Long-run coefficient estimates		
LNGDP$^+$	1.28**	0.00
LNGDP$^-$	0.10*	0.08
LNFDI	-0.04**	0.00
LNCAP	-0.12**	0.00
C	5.85**	0.00
Panel C: Diagnostic Tests		
Test	Test Statistic	P-value
R^2	0.92	
Adj. R^2	0.83	
F-test	4.68**	0.04
D-W test	2.53	
LM	2.49	0.16
HET	1.03	0.52
RRE	1.23	0.30
J-B	2.17	0.35
W_{SR}	22.80**	0.00
W_{LR}	8.23**	0.02

Note: ** and * denote significant level at 5% and 10%, respectively. GDP_POS and GDP_NEG indicate the positive and negative changes in the partial sum of economic growth, respectively. C represents the constant term. LM, HET, RRE, and J-B tests indicate Breusch-Godfrey Serial Correlation Lagrange Multiplier Test, Breusch-Pagan-Godfrey Heteroskedasticity Test, Ramsey's Reset Test, and Jarque-Bera Normality Test, respectively.
Source: Authors' Computation, 2020

Diagnostic and stability tests

The diagnostic tests reported in Table 5 include the R^2, adjusted R^2, F-statistic, Durbin Watson (D-W) statistic, Breusch-Godfrey Serial Correlation Lagrange Multiplier (LM) Test, Breusch-Pagan-Godfrey Heteroskedasticity (HET) Test, Ramsey's Reset (RRE) Test, and Jarque-Bera (J-B) Normality Test. The result of the R^2 shows that the exogenous variable accounts for 92 per cent of the variance in energy consumption, while the remaining 8 per cent is explained by other variables not included in the short-run model. This is confirmed by the adjusted R^2, where the other explanatory variables describe 83 per cent of the variance in energy consumption. The joint significance of the estimates is checked using the F-statistic and the result from Table 5 indicates that the estimates are statistically significant in the short-run. The D-W statistic of 2.53 indicates that no serial correlation occurs in the error term. As a result, the conclusions from these estimates are accurate and not misleading.

The LM test is used to check for the absence or otherwise of serial correlation in the residual obtained from the model. From the result, the residuals are free from autocorrelation since the LM test statistic is insignificant. This corroborates the Durbin Watson (DW) statistic from the short-run estimates. In the same way, there is no evidence of heteroskedasticity in the model as supported by the acceptance of the null hypothesis of constant error variance with insignificant HET test statistic. The RRE test being insignificant shows that the model is well specified. In other words, it implies that the functional form is correct and there is a lack of misspecification. To end this, the insignificant J-B statistic suggests that the model is also well specified and the errors are normally distributed.

Furthermore, it is clear that economic growth has short- and long-run asymmetric effects on energy consumption in Nigeria as the sums of short-run coefficient estimates of the positive and negative shocks to economic growth are substantially different. This is seen in the 22.80 Wald test statistic for short-run estimates of the coefficient (W_{SR}). Similarly, the long-run coefficient estimate of the cumulative function of positive changes of economic growth is significantly different from the coefficient attached to the cumulative function of negative changes of economic growth as reflected in the significant Wald test statistic (W_{LR}) of 8.23. Put differently, W_{SR} and W_{LR} test statistics imply that the null hypotheses of both short- and long-run symmetries are rejected but the alternative hypotheses of asymmetries are accepted. This is also supported by Figure 5 which shows the dynamic impacts on energy consumption of the positive and negative shocks of economic growth. This shows that rising economic growth greatly influences energy consumption as compared to a decline in Nigeria's economic growth. That is, energy use is more rapidly responding to the cumulative effect of positive economic changes as opposed to the cumulative effect of negative economic growth changes.

The accumulated sum of recursive residuals (CUSUM) and the accumulated sum of squares of recursive residuals (CUSUMSQ) are used in testing the stability of the short- and long-run estimates. As shown in Figure 6, the estimates are stable for both ARDL and NARDL models over the study period since the CUSUM and CUSUMSQ lines fall within the boundaries at 5 per cent significance level.

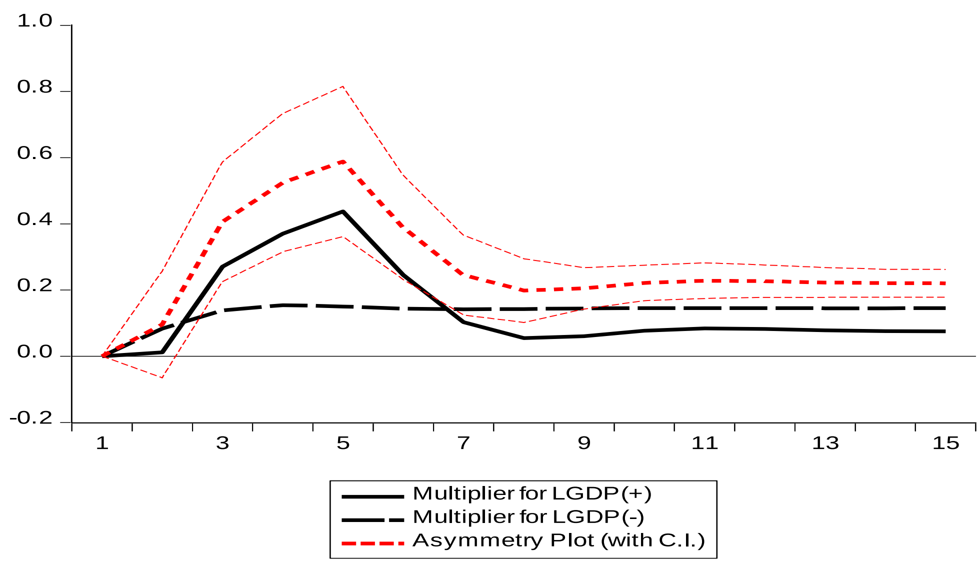

Figure 5: Cumulative effects of economic growth on energy consumption
Source: Authors' Computations

Figure 6: (a) Accumulated CUSUM and (b) CUSUM of Squares Plots
Source: Authors' Computations

Conclusion

Empirically, this study investigates the asymmetric nexus between Nigeria's economic growth and energy consumption between 1971 and 2018. The study employs NARDL model to take care of economic growth anomalies, that is, we use the NARDL model to examine the effects of negative and positive shocks to economic growth on energy consumption. The Wald tests demonstrate the existence of economic growth asymmetric impacts, and so also the multiplier graph. As indicated from the results, increases in the positive shocks to economic growth significantly reduces and increases energy consumption in the short and long-run, respectively. Energy consumption is observed to be rising in both the short- and long-run due to an increase in the negative shocks to economic growth, but its impact in the short-run is insignificant. However, foreign direct investment has the same extent of adversely impacting energy consumption in both the short- and long-run. Capital has a conflicting effect on energy consumption, with a long-run negative and a short-run positive effect. From these findings, it is inferred that economic growth has asymmetric effects on energy consumption and that the effect of positive shocks to economic growth on energy consumption is greater than that of negative shocks. In reference to economic growth, the findings imply that whether there is an increase or a decrease in economic activities in the long-run, energy use will increase but energy use increases more with an increase in economic activities than a decrease in economic activities. Also, any attempt to increase investment by foreigners would not increase energy consumption either in the short- or long-run. This is because most of these foreigners, as a result of energy failure in Nigeria, usually generate their means of energy supply by transferring energy-efficient technologies from their countries. This also provides the argument for a short-run negative relation between energy consumption and capital.

Based on these findings, we recommend that the Nigerian government should ensure energy supply stabilization as increasing economic growth amounts to increased energy consumption. If energy supply is stable, investors will rely solely on provided clean energy that will translate into increased investment and government revenue because it will have a multiplier effect on economic growth. Finally, other studies can examine the asymmetric effects of foreign direct investment and capital on Nigerian energy consumption, as against the symmetric effects of these variables on energy consumption. Additionally, future research can employ another indicator of energy consumption, for instance, electricity use, and see if the findings would be largely similar.

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