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ABSTRACT

A handful number of studies have sought to find a proper modeling strategy that captures the true dynamic relationship between electricity consumption and economic growth in Nigeria. Most of these studies have assumed a linear relationship in describing the pattern of behaviour in electricity-growth nexus. Departing from previous studies in the literature, this paper assumes both dynamic and asymmetric modelling approach in investigating the relationship between electricity Consumption and economic growth in Nigeria during the period 1971 to 2017, using the Non-Linear Autoregressive Distributed Lag (NARDL). Our findings confirmed the existence of both the long and short run asymmetric relationship between electricity consumption and economic growth. The study further shows that in the long run, decline in electricity (negative changes) has a reducing impact on economic growth. The implication of this is that in order to avoid reduction in economic growth that could be associated with decline in electricity consumption, policy makers should strive to maintain positive economic growth.

Keywords: Electricity Consumption, Economic growth, NARDL Asymmetric Modelling.

1. Introduction

The need to understand the links between electricity consumption and economic growth has accentuated the renewed interest in electricity-growth nexus studies in economic literature. A regular supply of Electricity has been established as one of the most crucial factors which can support and sustain paths of economic growth in developing countries like Nigeria. Electricity is considered one of the main inputs of the production process and will have a significant impact on the economic activities of these countries (Osman, *et al.* 2016). Recently, the U.S. Energy Information Administration (EIA, 2013) profoundly articulated that there is a strong correlation between these two variables. Huang and Yang (2012) opined that not only can electricity consumption improve the quality of living and reduce poverty; it is instrumental to industrialization and technological advances. A good electricity supply not only improves the quality of life of its users but also has the potential to improve the industrial output of a country and therefore, can have positive impacts on a country's growth and development prospects.

In recent times, there has been a voluminous body of literature focusing on the connection and appropriate modelling approach to examining the relationship between electricity consumption and economic growth. The most recent studies in this area include Osman *et al*. (2016), Kim (2015), Cowan *et al.* (2014), Hu and Lin (2013), Abbas and Choudhury (2013), Shahbaz and Lean (2012), Bildirici *et al*. (2012), and Gurgul and Lach (2011), among others. The different authors however, have reported conflicting results due to a number of factors such as differences in data set, variables selection, model specification, the time periods and country of studies, as well as the econometric approaches used by the different authors (Sheng et al., 2007; Abosedra et al., 2009, Payne 2010). At the heart of empirical investigation on the nexus between electricity consumption and economic growth lies two contemporary issues. The first concerns the sign of the relationship between the variables, of which overwhelming support is in favour of a significant positive co-integration between the two-time series variables[1]. The second issue relates to the granger causal effects between electricity consumption and economic growth. This aspect, however, has appeared to be more contentious within the electricity consumption-growth debate as would be seen under the literature review section.

Given the above dynamics and linkages between electricity consumption and economic growth, the present study seeks to re-examine the subject in the context of Nigeria. The issue of whether electricity can affect growth is particularly important in the Nigeria case, given the central role of electricity in the country's efforts to promote growth and development in virtually all aspects of the economy. It is believed that the amount of electricity consumption is a real-time reflection of the economic development situation of the country, hence, a full understanding and in-depth study of the relationship between the two is of fundamental importance to both policymakers and politicians in designing and formulating an effective electricity energy policies.

Although existing studies have broadly shown whether electricity consumption is a factor of economic growth and/or vice versa, it is necessary to find their cointegrated or long-run equilibrium relationships with a more rigorous and recent advances made in econometric modelling of time series variables. This study therefore contributes to existing literature in three folds. First, the unit root properties of electricity consumption and economic growth are

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[1]. See Payne (2010) and Zhang et al. (2017) for an extensive and comprehensive review of the existing literature, particularly on the different hypotheses tested, methodological issues, and variables selected and model specifications.

investigated by applying linear and nonlinear unit root tests. Previous findings reveal conflicting results that suffer from methodological issues which could hinder appropriate policy formulation (Toda and Yamamoto, 1995). The unit root properties of the series used in the traditional unit root test such as ADF (Dickey and Fuller, 1981), PP (Philips and Perron, 1988), and KPSS (Kwiatkowski et al. 1992), ADF-GLS (Elliott et al. 1996) may provide ambiguous empirical results due to their bias and low power to reject the null hypothesis especially when they are nonlinear. Alternatively, this study employs ZA unit root test (Zivot-Andrews, 1992) and Perron (1997). The test provides superior empirical results containing information about unknown single structural break occurring in the series. Second, an interesting aspect of the existing literature is that the relationship between electricity consumption and growth may differ between short run and long run. Recent research has further suggested that the traditional presumption that the electricity-growth relationship can be well approximated by a simple linear functional form is misleading and that a range of nonlinearities exist in the relationship (Shahiduzzaman and Alam, 2012). For this reason, the present paper uses the Non Linear Autoregressive Distributed Lag (NARDL) bounds testing procedure to complement the current literature by analyzing the long run equilibrium relationship between electricity consumption and economic growth using annual data from 1971 to 2017. The Nonlinear ARDL approach developed by Shin *et al.*(2014) is particularly applied in examining the nonlinear effect of electricity consumption and economic growth. Most studies examine the relationship between electricity consumption and economic growth on the assumption that such a relationship, if at all exists, is linear. In practice, such variables may share nonlinear relationships. Thus, inferences from studies which assumed linearity could be very misleading. (iii) We present fresh empirical findings for Nigeria using an extended annual time series while departing from linearity assumption of the previous studies that make their studies restrictive. (iv) Lastly, as far as we know this is the first paper that examine the connection between electricity consumption and economic growth in Nigeria from an asymmetric perspective.

2. Literature Review

Empirical literatures on energy consumption and growth are quite rich and diverse. However, majority of the studies on electricity energy consumption and economic growth focus on either the direction of causality or the nature of interaction / cointegration between the two variables, using various granger causality and cointegration techniques. The general observation from the majority of the study is that strong connection exist between electricity consumption and economic growth. However, empirical findings on the direction of causality are rather mixed. The debate on whether electricity consumption causes economic growth, or vice versa, and whether there exists a bidirectional causality between them, or if there is no relationship between them has been synthesised into four hypothesis namely; the growth hypothesis, the conservation hypothesis, the feedback hypothesis and the neutrality hypothesis (Jumbe, 2004, Payne, 2008), in both the single-country and multi-countries studies.

For the growth hypothesis, electricity consumption plays an important role in economic growth. If the causality is from the electricity consumption to economic growth, any decrease/increase in the electricity consumption could lead to a fall (rise) in income. The country specific studies that found uni-directional relationship running from electricity to economic growth include: Yoo and Kim (2006) for Indonesia, Yosof and Latif (2007) for Malaysia, Bohm (2008) for Slovak Republic, Sarker and Alam (2010) for Bangladesh, Solarin (2011) for Botwana, (Javi *et al*, 2013) for Pakistan, Nazlioglu et al.(2014) for Turkkey, Phiri and Nyoni (2018) for South Africa. The conservation hypothesis is based on the contention that energy consumption should not affect economic growth because it represents too small of a proportion of a country's gross domestic product. It implies that energy conservation policies that curtail energy consumption would have little or no adverse effects on economic growth. Unidirectional causality running from economic growth to electricity consumption lend support for this hypothesis. Studies that found uni-directional causality running from economic growth to electricity consumption include Ho and Siu (2007), Narayan and Prasad (2008), Ciarreta and Zarraga (2010) and Shahbaz and Feridun (2012), Sekantsi et al. (2016) and Liu et al (2018) in Hong Kong, Hungary, Spain, Pakistan, Lesotho, and Beijing respectively. The feedback hypothesis implies that there is two-way (bidirectional) causality between electricity consumption and economic growth. This suggests that electricity consumption and economic growth are interdependent and thus complement each other. Some country specific studies that support the feedback hypothesis include: Zachariadis and Pashouortidou (2007) for Cyprus, Öztürk and Acaravci (2010) for Hungary and Shahbaz and Tiwari (2011) for Romania, Shahbaz and Lean (2012) for Pakistan, Aslan (2014) for Turkey, and

Kyophilavong *et al.*(2017) for Lao PDR. Lastly, the neutrality hypothesis suggests the absence of a causal relationship between electricity consumption and real GDP. This implies that any policy aimed at either increasing or decreasing the electricity consumption and/or economic growth will have no negative effect on the other. The following country level studies showed no causality between electricity consumption and economic growth: Yusof and Latif (2007) for Malaysia, Narayan and Singh (2007) for China, Narayan and Prasad (2008) for Turkey, Halicioglu (2009) for Turkey and Payne (2010) for USA, Dorgan (2015) for Turkey and Bah and Aslan (2017) for South Africa.

Studies have also been conducted at the multi-country levels. The various authors' have emphasized the existence of electricity consumption –growth nexus and have validated the four hypothesis in their various studies for different countries. Wolde-Rufael (2006) investigated the long-run equilibrium and the causality relationship between electricity consumption and real GDP per capita (economic growth) for 17 African economies using the Bounds testing approach to cointegration. The results show that cointegration is only found in nine out of seventeen countries. However, causality analysis implies that electricity consumption Granger-causes economic growth (growth hypothesis) in Tunisia, Benin, Congo and the Democratic Republic of Congo whereas economic growth Granger-causes electricity consumption (Conservative hypothesis) in Nigeria, Senegal, Cameroon, Ghana, and Zimbabwe. Furthermore, there exists bi-directional causality (Feedback hypothesis) between the variables in case of Egypt, Gabon, and Morocco. Squalli (2007) in an ARDL bound test approach shows evidence of a long-run relationship between electricity consumption and economic growth for all OPEC members. The Granger causality tests supported growth hypothesis for Indonesia, Nigeria, United Arab Emirates and Venezuela, conservation hypothesis for Algeria, Iraq, Kuwait and Libya, and feedback hypothesis for Iran, Qatar and Saudi Arabia. Chen et al. (2007) employed panel causality tests based on the error correction model over the 1971–2001 to investigate the relationship between electricity consumption in 10 industrialized and low income countries of Asian region. The study validated the growth hypothesis for Hong Kong, conservative hypothesis for India, Malaysia, Philippines, and Singapore, while neutrality hypothesis is held for China, Indonesia, Korea, Taiwan, and Thailand. Acaravci and Ozturk (2009) have explored causality issue between electricity consumption per capita and GDP per capital in 15 transition economies namely Albania, Belarus, Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Macedonia, Moldova, Poland, Romania, Russian Federation, Serbia, Slovak Republic and Ukraine. The Pedroni panel and error correction method used do not provide support for cointegration for the variables and economic growth is not stimulated by an increase in electricity consumption in such economies. Applying heterogeneous panel data analysis. Osman *et al.* (2016) investigate the relationship between electricity consumption and economic growth in the GCC countries using annual data from 1975 to 2012. The panel results provide evidence for bi-directional causality between economic growth and electricity consumption in these countries. In a similar study, Furuoka (2017) through panel granger causality and Dumitrescu–Hurlin panel causality tests, validated conservative hypothesis for the countries in the Baltic region

Furthermore, researchers and academic connoisseurs alike are increasingly considering the possibility of accounting for asymmetric adjusting behavior in the relationship between electricity consumption and economic growth by applying different nonlinear estimation techniques in their data analysis. Different threshold models have been developed and used to capture asymmetries in the electricity consumption-economic growth literature. Chief among them are regime-switching threshold autoregressive (TAR) developed by Bruce Hansen (1996, 1997, 1999, 2000); smooth transition regression (STR) models (see Luukkonen et. al. (1988), Teravirsta (1994) and Van Dijk et. al. (2002); threshold vector error correction (TVEC) model; smooth transition vector error correction model (STVEC) model; and Markov switching error correction mechanism (MSECM) (see Table 1).

Table 1a: The summary of Single-country studies on the electricity-growth nexus

Growth Hypothesis

No	Authors	Period	Countries	Methodology	Direction of Granger causality
1.	Yoo and Kim (2006)	1971-2002	Indonesia	VAR Granger Approach	EC → GDP
2.	Yusof and Latif (2007)	1980-2006	Malaysia	Johansen Cointegration and Engle-Granger Causality Approach	EC → GDP
3.	Bohm (2008)	1960-2002	Slovak Republic	Granger causality test	EC → GDP
4.	Sarker and Alam (2010)	1973-2006	Bangladesh	Granger-causality test	EC → GDP
5.	Solarin A. A (2011)	1980-2008	Bostwana	cointegration, and Granger causality test	EC → GDP
6.	Javid et al (2013)	1971- 2008.	Pakistan	Dolado–Lutkepohl testVector Autoregression (VAR) Granger causality test	EC → GDP
7.	Nazlioglu et al.(2014)]	1967– 2007	Turey	ARDL model and VECM Granger causality tests	EC → GDP
8.	Phiri and Nyoni, (2018)		South Africa	momentum-threshold cointegration method	EC → GDP

Conservative Hypothesis

No	Authors	Period	Countries	Methodology	Direction of Granger causality
9.	Ho and Siu (2007)		Hong Kong	Unit root test; Error correction model	GDP → EC
10.	Narayan and Prasad (2008)	1960 – 2002	Hungary	Granger causality	GDP → EC
11	Ciarreta and Zarraga(2010)	1971-2005	Spain	Toda and Yamamoto (1995) Granger Causality Test	GDP → EC
12.	Shahbaz and Feridun (2012)	1971 – 2008.	Pakistan	(ARDL) boundsTest, Toda-Yamamoto andWald-test causality tests	GDP → EC
13.	Sekantsi (2016)	1972-2011	Lesotho	ARDL bond test and Granger causality test	EC ↔ GDP

14.	Liu et al (2018)	2005Q1 - 2016Q3	Beijing (China)	Granger causality analysis	GDP → EC

Feedback Hypothesis

15.	Zachariadis and Pashourtidou (2007)	1960-2004	Cyprus	VECM Cointegration and Causality	EC ↔ GDP
16.	Öztürk and Acaravcı (2010)	1980 – 2006	Hungary	Bound test (ARDL)	EC ↔ GDP
17.	Shahbaz,and Tiwari (2011)	1980 – 2008	Romania	ARDLBound test and Toda Yamamoto Granger causality	EC ↔ GDP
18.	Shahbaz and Lean (2012)	1972-2009	Pakistan	ARDL model and Granger causality Tests	EC ↔ GDP
19.	Aslan (2014)	1968-2008	Turkey	ARDL bond test and Granger causality test	EC ↔ GDP
20.	Kyophilavong *et al.*(2017)	1984–2012	Lao PDR	ARDL bond test and Granger causality test	EC ↔ GDP

Neutrality Hypothesis

21.	Yusof and Latif (2007)	1980-2006	Malaysia	Johansen Cointegration and Engle-Granger Causality Approach	No Causality
22.	Narayan & Singh (2007)		China	ARDL, VECM	No Causality
23.	Narayan and Prasad (2008)	1960-2002	Turkey	Bootstrapped Granger-causality	No Causality
24.	Halicioglu (2009)		Turkey	Granger causality, ARDL cointegration	No Causality
25.	Payne (2010)		USA	Toda-Yamamoto causality tests; Granger-causality test	No Causality
26.	Dorgan (2015)	1990– 2012	Turkey	ARDL, Johansen cointegration and the Gregory–Hansen cointegration	No Causality
27.	Bah and Azam (2017)		South Africa	ARDLBound test and Toda Yamamoto Granger causality	No Causality

Table 1b: The summary of multi-country studies on the electricity-growth nexus					
No	**Authors**	**Period**	**Countries**	**Methodology**	**Direction of Granger causality**
28.	Wolde-Rufael (2006)	1971–2001	17 African	ARDL Bounds testing; Toda-Yamamoto's test for causality – Augmented VAR	EC $\rightarrow$ GDP (Benin, Congo DR, Tunisia)
					GDP $\rightarrow$ EC (Cameroon, Ghana, Nigeria, Senegal, Zambia, Zimbabwe)
					EC $\leftrightarrow$ GDP (Egypt, Gabon, Morocco)
					EC $\nleftrightarrow$ GDP (Algeria, Congo Rep., Kenya, South Africa, Sudan)
29.	Squalli (2007)	1980–2003	11 OPEC	ARDL Bounds testing; Toda-Yamamoto's test for causality – Augmented VAR	EC $\rightarrow$ GDP (Indonesia, Nigeria, UAE, Venezuela)
					GDP $\rightarrow$ EC (Algeria, Iraq, Kuwait, Libya,)
					EC $\leftrightarrow$ GDP (Iran, Qatar, Saudi Arabia)
30.	Chen et al. (2007)	1971–2001	10 Asian	Johansen-Juselius; Granger causality–VECM	EC $\rightarrow$ GDP (Hong Kong)
					GDP $\rightarrow$ EC (India, Malaysia, Philippines, Singapore)
					EC $\nleftrightarrow$ GDP (China, Indonesia, Korea, Taiwan, Thailand)
31.	Öztürk and Acaravcı (2009)	European and Eurasian Countries	1990-2006	Pedroni cointegation and ECM	EC $\nleftrightarrow$ GDP
32.	Narayan and Prasad (2008)	1960–2002	30 OECD	Toda-Yamamoto's test for causality with bootstrapping approach	EC $\rightarrow$ GDP (Australia, Czech Rep., Italy, Slovak Rep., Portugal)
					GDP $\rightarrow$ EC (Finland, Hungary, Netherlands)
					EC $\leftrightarrow$ GDP (Iceland, Korea, UK)
					EC $\nleftrightarrow$ GDP (Spain Sweden ,Switzerland, USA, New Zealand , Norway ,Poland, Luxembourg, Mexico, Japan, Ireland, France, Germany, Greece, Denmark, Austria ,Belgium ,Canada, Sweden)
33.	Bildirici *et al,* (2013)			ARDL Bounds testing;	EC $\rightarrow$ GDP (US, UK, Canada, Japan, China, India, Brazil, Italy, France, Turkey and South Africa)
					GDP $\rightarrow$ EC (India, Turkey, South Africa, Japan, UK, France and Italy)
34.	Karanfil and Li (2015)	1980-2010		Panel ARDL, and Cointegration	GDP $\rightarrow$ EC (East Asia and Pacific, the Middle East and North Africa, and lower middle panels)

					A long-run cointegration relationship exist between these two variables, implying the feedback hypothesis
35.	Osman et al. (2016)	1975-2012	GCC, High income and Upper middle income countries	Heterogeneous Panel and Panel Granger Causality	EC ↔ GDP (high income, upper middle income country panels and GCC)
					The results suggest that there is a short- run and a great long-run equilibrium relationship between the variables
36.	Osman *et al.* (2016)	1975-2012	GCC countries (Bahrain, Kuwait, Oman, Qatar, KSA, UAE)	Heterogeneous Panel and Panel Granger Causality	EC ↔GDP
37.	Furuoka (2017)	1992–2011	Baltic region (Estonia, Latvia and Lithuania)	Panel Granger causality and Dumitrescu–Hurlin panel causality tests	GDP → EC

Notes:

Direction of Causality Column: The uni-directional causality from electricity consumption to economic growth is indicated by GDP → EC, uni-directional causality from electricity consumption to economic growth by EC →GDP, bi-directional causality between electricity consumption and economic growth by EC ↔GDP and no causal relation between both variables by EC↮ GDP.

3 Model and Methodology

Following the literature on energy and economic growth nexus, we model the relationship between economic growth and electricity consumption based on the neoclassical growth model in the standard Cobb-Douglas production function framework. Originally, the model did not capture energy as a factor of production, but only considers the economy to be a closed system in which goods are produced with capital and labor inputs. However, the literature has established that energy, along with capital and labor are the basic elements of economic growth in developed countries (Shafiei, Salim and Cabalu, 2013, Bah and Azam, 2017). The modified Cobb-Douglas model becomes:

$$Y_t = AK_t^{\alpha} L_t^{\beta} E_t^{\gamma} \quad (1)$$

Where *K* is capital, *L* is labor, *E* is energy and *γ* is the elasticity of output with respect to energy. Incorporating other factors found relevant in the literature on electricity-economic growth nexus, our empirical model for this study can be derived as follows:

$$ly_t = \beta_0 + \beta_1 lelc_t + \beta_1 linv_t + \beta_1 linf_t + e_t \quad (2)$$

In eq. (2) y_t is the dependent variable and is represented with real GDP per capita, $elct_t$ is electricity consumption, investment, and inf_t is inflation. e_t is the error term, β_0 is the constant term and β_1, $\beta_2, and\ \beta_3$ are the coefficients of the model. All the variables are expression in natural logarithm form. Natural log transformation can assist in avoiding the heteroscedasticity problem as well as inducing stationarity in the n the variance covariance matrix (Narayan and Smyth, 2005)

While several econometric methods have been proposed for investigating long-run equilibrium (cointegration) among time series variables, the few specific studies on Nigeria have used conventional methods such as Vector Auto Regressive (VAR) and Error Correction Model (ECM), Vector Error Correction Modelling and the Pairwise Granger Causality test. One drawback of the above methods is the possibility of overlooking nonlinear relations as discussed in the previous sections. To empirically establish the long-run relationships between the electricity consumption and economic growth, this paper adopts the non-linear autoregressive distributed lag (NARDL) approach of Shin *et al*. (2014) to model the relationship between our variables of interest. The NARDL is an asymmetric extension to the well-known ARDL model of Pesaran and Shin (1999) and Pesaran et al. (2001), often used to capture both long run and short run asymmetries in a variable of interest. Van Hoang et al (2016) highlight some of the advantages of using the NARDL approach as follows. First, it allows modelling the cointegration relation that could exist between the dependent and independent variables. Second, it permits testing both the linear and nonlinear cointegration. Third, it distinguishes between the short- and long-run effects from the independent variable to the dependent variable. Though these advantages may also be valid for nonlinear threshold Vector Error Correction Models (VECM) or smooth transition models; however, these threshold models may suffer from the convergence problem due to the proliferation of the number of parameters. This is not the case with the NARDL model. Fourth, unlike other error correction models where the order of integration of the considered time series should be the same, the NARDL model relaxes this restriction and allows combining data series having different integration orders.

Asymmetric ARDL Model

In order to exploit more useful dynamics in our model, NARDL of Shin *et al.* (2014) which appears less computationally intensive compared to other asymmetric models and which does not require identical order of integration [i.e. $I(1)$] for all the series in the model is expressed in the following general form of nonlinear (asymmetric) ARDL model:

$$\Delta y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2^{+} y^{+}_{t-1} + \alpha_3^{-} elc^{-}_{t-1} + \alpha_4 \lg cf_{t-1} + \alpha_5 l\inf_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta y_{t-j} + \sum_{j=1}^{q} ({}_j\Delta\gamma_j^{+} elc_{t-j} + \gamma_j^{-} \Delta elc^{-}_{t-j})$$
$$\sum_{j=1}^{r} \varphi_j \Delta \lg cf_{t-j} + \sum_{j=1}^{s} \xi_j \Delta \inf_{t-j} + \varepsilon_t \qquad (3)$$

The decomposition of elc_t into its positive Δelc_t^{+} and negative Δelc_t^{-} partial sums for increases and decreases follows the approach proposed by Shin *et al.* (2014) in order to accommodate the potential short- and long-run. This method is considered to have computational advantages over the dummy variable approach (see Van Hoang *et al.*, 2016). The elc_t^{+} and elc_t^{-} are defined theoretically as:

$$elc_t^{+} = \sum_{j=1}^{t} \Delta elc_j^{-} = \sum_{j=1}^{t} \max(\Delta p_j, 0)$$

$$elc_t^- = \sum_{j=1}^{t} \Delta elc_j^- = \sum_{j=1}^{t} \min(\Delta p_j, 0)$$

We can re-specify equation (3) to include an error correction term thus:

$$\Delta y_t = \tau\xi_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta y_{t-j} + \sum_{j=1}^{q} ({}_j\Delta\gamma_j^{\ +} EC_{t-j} + \gamma_j^{\ -}\Delta EC^-_{\ t-j}) + \sum_{j=1}^{r} \varphi_j \Delta \lg cf_{t-j} + \sum_{j=1}^{s} \xi_j \Delta \inf_{t-j} + \varepsilon_t \quad (4)$$

In equation (4), the error-correction term that captures the long run equilibrium in the NARDL is represented as ξ_{t-1} while its associated parameter (τ) [the speed of adjustment] measures how long it takes the system to adjust to its long run when there is a shock. The error correction term can be expressed as $\xi_{t-1} = y_{t-1} - \varphi_0 - \varphi_1 elc^+_{\ t-1} - \varphi_2 elc^+_{\ t-1}$. The long-run coefficients with respect to the negative and positive changes of the independent variables can be computed as $L^+ = -{\alpha_2^{\ +}}/{\alpha_1}$ and $L^- = -{\alpha_3^{\ -}}/{\alpha_2}$. These coefficients measure the relationship between electricity consumption and economic growth at the long-run equilibrium. The long-run symmetry can be tested by using a Wald test of the null hypothesis that $\alpha_2^{\ +} = \alpha_3^{\ -}$. Similarly, the short-run adjustment of economic growth (GDP_t) to a positive or negative variation of electricity consumption (EC_t) is captured by the parameters $\gamma_j^{\ +}$ and $\gamma_j^{\ -}$, respectively. The short run symmetry can be tested by using a standard Wald test of the null hypothesis that $\gamma_j^{\ +} = \gamma_j^{\ -}$, for all j =0, …, r. Hence, in this setting, in addition to the asymmetric long run relation, the NARDL captures the asymmetric short-run influences of electricity consumption on output.

We carry out our empirical implementation of the nonlinear ARDL approach along the following steps: First, we start the analysis by doing some pre-tests. In this regard we employ unit root test to determine the order of integration of the variables. Although, the ARDL approach to cointegration is suitable irrespective of whether the series are I(0) or I(1), the procedure will however crash in the presence of I(2) series so, the unit root test is carried out to ensure that all variables are stationary at most in their first differences. To address this, we apply the widely used ADF and PP unit root tests for establishing the variables' orders of integration. In the second step, Once the variables' order of integration is verified, we estimate equation (6) using the standard ordinary least squares (OLS) method, and the lag length is chosen based on the information criterion SIC or general-to-specific procedure to arrive at the final specification of the NARDL model by trimming insignificant lags. Third, we test for the existence of long run relationship among variables, for linear and nonlinear specifications as in equation (2) and (3) respectively, using bounds testing for cointegration of Pesaran et al. (2001) and Shin et al. (2011) in an unrestricted error correction model as in equation (6). The bounds testing procedure is based on the F-statistics for the joint significance of the coefficients of the lagged levels of the variables. The null hypothesis of no cointegration i:e ; $H_0 : \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4$ is tested against the alternative hypothesis $H_1 : \alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4$. In the final step, as soon as the long run equilibrium relation exists among variables, we estimate the long run asymmetric impact of electricity consumption on economic growth. In the NARDL framework, the asymmetric responses of the dependent variable to positive and negative variations of the independent variable are respectively captured by the positive and negative dynamic multipliers associated with a one percent change in oil_t^+ and oil_t^- as follows:

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial y_{t-1}}{\partial oil_{t-1}^+}; \ m_h^- = \sum_{j=0}^{h} \frac{\partial y_{t-1}}{\partial oil_{t-1}^-}, \ h = 0,1,2,...$$

Note that as $h \to \infty$, $m_h^+ \to L^+$ and $m_h^- \to L^-$ by construction (with $L^+ = -\alpha_3^+ / \alpha_2$ and $L^- = -\alpha_3^- / \alpha_2$ as the long run coefficients explained above)

Based on the estimated multipliers, one can observe, following a variation affecting the system, dynamic adjustments from the initial equilibrium to the new equilibrium between the system variables. Where Δ is a difference operator, residuals, μ_i are independently and normally distributed (i.i.d.) with zero mean and constant variance and $ECT_{i-1}$is the error correction term resulting from the long-run equilibrium relationship via ARDL model and $\alpha$and $\beta$are parameters to be estimated. $\delta$is a parameter indicating the speed of adjustment to the equilibrium level after a shock. The F statistics or Wald test on the lagged explanatory variables of the ECT indicates the significance of the short-run causal effects. The ECT_{t-1} variable will be excluded from that model if the variables are not cointegrated. The optimal lag length p is determined by the Akaike's Information Criterion (AIC) because of its superior performance in small sample (Lütkepohl, 2005). Next, we apply the Likelihood Ratio (LR) statistics to ascertain the direction of Granger causality between the variables of interest. In this study, we test the following hypotheses:

$H_0 : \alpha_2 = \alpha_3 = 0$ Implying that GDP does not Granger-cause EC.

$H_0 : \beta_2 = \beta_3 = 0$ Implying that EC does not Granger-cause GDP

4. Data and results

4.1. Sample description

For the purpose of empirical analysis, 46 years annual time series data, covering periods 1971–2017 is used. The data on GDP per capita at constant 2010 USD (US dollar) is a measure of economic growth, and the gross capital formation (% of GDP) is used as a measure of investment. Electric power consumption (kWh per capita) is employed to measure electricity consumption and consumer price index is used for inflation to capture macroeconomic instability of the country. All data are sourced from the World Development indicators of World Bank database (2019).

The descriptive statistics and pair-wise correlations are reported in Table 2. The standard deviation in the summary statistics indicates that inflation is the series with the highest volatility while economic growth is the least volatile. Electricity consumption is less volatile compared to gross capital formation. The Jarque–Bera test suggests non normall distribution in the series as the null hypothesis of a normal distribution cannot be accepted. The values reported for the skewness and kurtosis show the presence of a potential asymmetry in the distribution of time-series data used. Hence, a justification for our use of NARDL (asymmetric) modeling approach for the empirical analysis.

Table 2: Descriptive Statistics

Variables	Obs	Mean	Std.Dev.	Min	Max	Skew.	Kurt.	Jargu-Bera
ly	47	7.471	.221	7.188	7.849	.166	1.593	4.094
lelc	47	4.443	.433	3.352	5.055	-.744	3.055	4.348
lgcf	47	3.757	.707	2.702	5.176	.19	2.083	1.929
l cpi	47	1.826	2.515	-2.153	5.367	-.167	1.503	4.604

The pairwise correlation matrix presented in Table 3 indicates a positive co-movement between electricity consumption and economic growth. This buttress the *a priori* expectations that electricity energy is important in promoting growth. Gross capital formation (investment) is inversely correlated with economic growth, while inflation positively co-moved with it. A negative correlation occur between gross capital formation and electricity, but inflation is negatively correlated with investment. Finally, the correlation matrix also indicates that there might not be a serious multicollinearity problem in the data as the coefficient of correlation in absolute term for all the variables were less than 0.8, which is a benchmark for the absence of multicollinearity problem based on econometrics rule of thumb for multicollinearity test.

Table 3: Pairwise correlations Matrix

Variables	(1)	(2)	(3)	(4)
(1) ly	1.000			
(2) lelc	0.203	1.000		
(3) lgcf	-0.274	-0.628	1.000	
(4) lcpi	0.252	0.768	-0.763	1.000

4.2. Tests for unit roots

Prior to conducting the cointegration tests, it is very important to check the time properties of each series for stationarity. The empirical investigation of the stationarity level of our series starts with application of the conventional unit root tests. Unit root analysis ensures that no variable is integrated at I(2) to keep away from spurious results. According to Ouattara (2004), if any variable is integrated at I(2) then computation of F-statistics for ARDL cointegration becomes senseless. Pesaran et al. (2001) critical bonds are based on assumption such as variables should be stationary at I(0) or I(1). Therefore, application of unit root tests is still necessary to ensure that no variable is integrated at I(2) or beyond. Table 4 presents the conventional unit root tests based on the Augmented Dickey and Fuller (1979), the Phillips and Perron (1988) and the Kwiatkowski, Phillips, Schmidt, and Shin (1992) (KPSS) tests, respectively, both with constant and trend term. Alhough these tests in general show that the variables are stationary in their first differences, they could be prone to error in the presence of structural breaks, hence, they could lead to misleading conclusions. Thus, ignoring structural breaks in the series may cause traditional unit root tests to provide vague empirical results.

To advance more reliable results, we proceed to unit root testing that is robust to structural break. The nonlinear unit root tests: the Perron test developed by Perron (1997), and the Zivot–Andrews test developed by Zivot and Andrews (1992) were employed. The Andrews–Zivot and the Perron tests are able to detect structural breaks in the transition parameter of time series process. The results are reported in Table 5 under the intercept and intercept and trend terms. We find that the economic growth, electricity consumption, investment, and inflation become stationary both at level and after first difference in the case of Zivot and Andrews, but achieve stationarity after first difference with Perron Test. The results again confirm that none of the variables are integrated of an order higher than one.

Table 4: Conventional (Linear) Unit root test results.

	ADF		**PP**		**KPSS**	
Specification / Variable	**Test Statistics**		**Test Statistics**		**Test Statistics**	
With constant Only	Level	1st Diff.	Level	1st Diff.	Level	1st Diff.
LY_t	-0.7878	-4.7446*	-0.8307	-4.9220*	0.2853*	0.2903*
$LELC_t$	-1.3998	-9.1190*	-2.5164	-9.3134*	0.7929	0.2399*
$LGCF_t$	-4.1939*	-3.8506*	-1.1617	-6.7556*	0.8812	0.1454*
$LINF_t$	-1.2380	-3.4404**	-0.8154	-3.3504**	0.8775	0.1874*
With constant & Trend						
LY_t	-1.2209	-5.5006*	-1.1302	-5.0926*	0.2099*	0.0795*
$LELC_t$	--3.1702	-9.0301*	-3.2274**	-9.6329*	0.1202	0.0868*
$LGCF_t$	-3.8027**	-5.7118*	-3.2806**	-6.8416*	0.1034*	0.0390*
$LINF_t$	-1.1674	4.1888*	-1.0768	-3.3408***	0.1406	0.1389***

Source: Authors' calculation using Eviews 10

*Notes: The ADF and PP critical values are based on MacKinnon (1996). The KPSS is based on Kwiatkowski et al. (1992). The optimal lag is based on the Akaike Information Criterion for ADF, while the bandwidth for PP and KPSS are automatically determined. The null hypothesis for ADF and PP tests is that a series has a unit root (non-stationary) and for KPSS that the series is stationary. *, ** and *** refer to 1%, 5% and 10% levels of significance, respectively.*

Table 5. Unit root tests with Structural breaks for the variables in levels and first difference

		Zivot and Andrew		**Perron**	
Variable	**Specification**	**Test statistic**	**Break point**	**Test statistic**	**Break point**
LY_t	Intercept	-4.5008*	1981	-4.6807	1980
	Intercept & Trend	-4.6405*	1981	-4.769	1980
$LELC_t$	Intercept	-4.1453*	1995	-4.1332	1994
	Intercept & Trend	-4.1264*	1994	-4.1491	1994
$LGCF_t$	Intercept	-4.4695	1984	-4.4204	1996
	Intercept & Trend	-4.9116**	1993	-4.8315	1993
$LINF_t$	Intercept	-4.1455*	1992	-4.1474	1991
	Intercept & Trend	-4.5094*	1992	-4.7568	1992
ΔLY_t	Intercept	-3.1437*	1988	-5.5872**	1983
	Intercept & Trend	-3.3959**	2002	-6.6980*	1983
$\Delta LELC_t$	Intercept	-8.9863*	2002	-10.5532*	2002
	Intercept & Trend	-9.0305*	2002	-10.3944*	2002
$\Delta LGCF_t$	Intercept	-.4.1401**	1989	-7.308*	1985
	Intercept & Trend	-4.1809	1989	-7.2556*	1981
$\Delta LINF_t$	Intercept	-5.6568*	1988	-5.1157***	1995
	Intercept & Trend	-5.7406*	1997	-5.9639*	1995

Source: Authors' calculation using Eviews 10

4.3. Bounds test for co-integration

The unique order of integration of the variables provide us with the supports to further investigate the long run relationship between the series by applying ARDL bounds testing approach to cointegration. An important area of concern in this regard is the selection of the optimal lag length. The appropriate lag length is prerequisite to continue the ARDL bounds testing to examine cointegration between the series. The SBC criterion are followed to choose lag length.

Sequel to the results of the respective unit root tests, we examine the lag-length tests based on a number of criteria (Table 3). We noted that 4 criteria (LR, FPE, and AIC) indicate a lag-length of 4, while SC indicates a lag-length of 1. Examining both the lags separately, we noted superior results in terms of cointegration and stability of the model when a lag-length of 3 is applied (Clarke & Mirza, 2006).

Table 6: Lag selection criterion.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-47.75331	NA	0.000130	2.407131	2.570963	2.467547
1	177.7083	398.4903	7.70e-09	-7.335270	-6.516107*	-7.033188*
2	196.9763	30.47032	6.75e-09	-7.487270	-6.012777	-6.943522
3	210.1720	18.41254	8.11e-09	-7.356835	-5.227012	-6.571422
4	239.7381	35.75439*	4.79e-09*	-7.987818*	-5.202664	-6.960739

Source: Authors' calculation using Eviews 10

Notes: * *refers to significance at 5% level. LL: log likelihood, LR: sequentialmodified LR test statistic, FPE: Final prediction error, AIC: Akaike Information Criterion, SC: Schwarz information criterion, HQ: Hannan–Quinn information criterion.*

Having determine the optimal lag length, the nest stage of our analysis is the ARDL bounds test. The results of the bounds test for cointegration, together with critical values of Pesaran and Pesaran (1997) are reported in Table 7. The table shows no evidence of cointegration when the linear form is specified, since the F-statistic 2.0646 is less than the lower critical bound. However, in the nonlinear specification of the model, the long-run relation exists as the F-statistic 6.5573 is greater than the upper critical bound at all levels of critical values. These findings indicate that any wrong specification may lead to a misleading conclusion with respects to whether the variables move together in the long-run or not. In order word, the results only confirms the presence of a long-run association for a nonlinear relationship. This further buttress the use of the NARL modelling approach of this study.

Table 7: Bounds Testing Cointegration

Model Specification	Linear			Non Linear			
Test statistic	Value			Test statistic	Value		
F-statistic	2.0646			F-statistic	6.5573		
	Citical Values				Citical Values		
Sig.	Lower bound	Upper bound	Decision	Sig.	Lower bound	Upper bound	
10%	2.72	3.77	No cointegration	10%	2.20	3.09	cointegration
5%	3.23	4.35	No cointegration	5%	2.56	3.49	cointegration
1%	4.29	5.61	No cointegration	1%	3.29	4.37	cointegration

Source: Authors' calculation using Eviews 10

Notes: Critical bounds automatically determined by Mfit 5 (Pesaran & Pesaran, 2009).

4.4 Nonlinear ARDL results

After confirming the order of integration of the variables and establishing the presence of asymmetric cointegration in the model, we proceed to selecting the best specification of the NARDL model for electricity consumption-Economic growth model. Table 8 presents the Wald test statistics for the null hypothesis of long- and short-run symmetry against the alternative of asymmetry. At 1% significant level, the results from the long-run and short run asymmetry tests show that electricity consumption affects economic growth in an asymmetric way. Thus, taking nonlinearity and asymmetry into account is important when analyzing the relationship between electricity consumption and economic growth in Nigeria.

Table 8. Long- and Short-run symmetry Tests.

Variable	Long-Run Asymmetry (WLR)		Short-Run Asymmetry (WSR)	
	F-Statistic	p-Value	F-Statistic	p-Value
lelc	9.4431	0.0046	11.76710	**0.0002**

Source: Authors' calculation using Eviews 10

*Notes: (1) WSR and WLR refer to the Wald statistics for the short- and long-run symmetry null hypotheses. (2) The numbers in the brackets are the p-values. (3) ***, **, and * indicate rejection of the null of symmetry at the 1%, 5%, and 10% levels, respectively.*

Having found evidence of asymmetry, we next analyze the coefficients of the long-run and short-run dynamics of the asymmetric ARDL model. The results as shown in Table 9 indicate that in general the estimated NARDL model is stable as the coefficient that relates to the lagged economic growth is negative and statistically significant. Gross capital formation (investment) has significant negative long-run effects on economic growth. However, inflation has no long run effect on economic growth.

Regarding electricity consumption, positive changes in electricity consumption has no effect on economic growth, while negative changes in the electricity consumption has a significant positive long-run effect on economic growth. Specifically, a statistically significant long run impact is detected only from the negative component (L_y^-).

Table 9. Results of asymmetric ARDL model estimation.

Variable	Coefficient	Standard Error	t Statistic	Probability
C	3.2592	0.7945	4.1024	0.0003
ly_{t-1}	-0.2321	0.0474	-4.9019	0.0000
$lelc_{t-1}^{+}$	0.0688	0.0433	-1.5875	0.1232
$lelc_{t-1}^{-}$	0.2374	0.1351	1.7577	0.0894
$lgcf_{t-1}$	-0.3106	0.1013	-3.0669	0.0047
$linf_{t-1}$	-0.0038	0.0118	-0.3231	0.7490
Δly_{t-3}	0.5644	0.1321	4.2735	0.0002
$\Delta linf$	-0.2267	0.0573	-3.9536	0.0005
$\Delta lgcf$	-0.1494	0.0787	-1.8983	0.0677
$\Delta lelc_{t-1}^{+}$	-0.1329	0.0623	-2.1341	0.0414
Δly_{t-2}	0.1986	0.1179	1.6843	0.1029
$\Delta lelc_{t-1}^{-}$	0.2160	0.1263	1.7104	0.0979
$\Delta lelc_{t-3}^{+}$	0.1114	0.0646	1.7227	0.0956
$\Delta lgcf_{t-2}$	-0.1205	0.0610	-1.9741	0.0580
L_y^{+}	0.2964	L_y^{-}	1.0228	
R^2	0.7103	W_{LR}	9.4431(0.0046)	
χ_{SC}^2	1.8561(0.1737)	W_{SR}	11.7671(0.0002)	
χ_{FF}^2	3.0448 (0.0050)	AIC	-3.5269	
χ_{NOR}^2	1.2928 (0.5239)			
χ_{HET}^2	2.5007 (0.1217)			

Note: The superscripts "+" and "−" denote positive and negative partial sums, respectively. L^+ *and* L^- *are the estimated long-run coefficients associated with positive and negative changes, respectively.* χ_{SC}^2, χ_{FF}^2, χ_{NOR}^2, χ_{HET}^2 *denote LM tests for serial correlations, the RESET test in Ramsey's test for functional misspecification, Jarque-Bera test on normality, and heteroscedasticity respectively.* W_{LR} *and* W_{LR} *refer to the Wald test for the null of long-run symmetry,* W_{SR} *and* W_{SR} *refer to the Wald test for the null of the additive short-run*

** Denotes 5% significance level*

Analytically, the long-run coefficient on $lelc^-$ is 1.02 indicating that, a negative change, say a 1% decrease in electricity consumption at 5%, results in a decrease of 1.02% in economic growth in the long run. This indicates that a greater effect of the decrease in electricity-growth nexus in Nigeria is coming from the negative changes. The significant short-run coefficients for electricity consumption also confirm the presence of short-run asymmetry of our data series.

The lower part of Table 9 presents some diagnostic tests of the estimated model. The tests for serial correlation LM (χ^2_{NOR}), Normality (χ^2_{sc}) and ARCH (χ^2_{HET}) test for heteroscedasticity indicate that the model estimated is well specified.

To further examine the structural stability of the model, Figures 1 and 2 shows the graphs of the CUSUM and CUSUMSQ statistics of the parameter stability. In both cases, the statistics lie within the critical bounds and this implies that all the coefficients of the estimated model are stable.

Figure 1: The Cumulative Sum Graph based on the NARDL Model Estimation

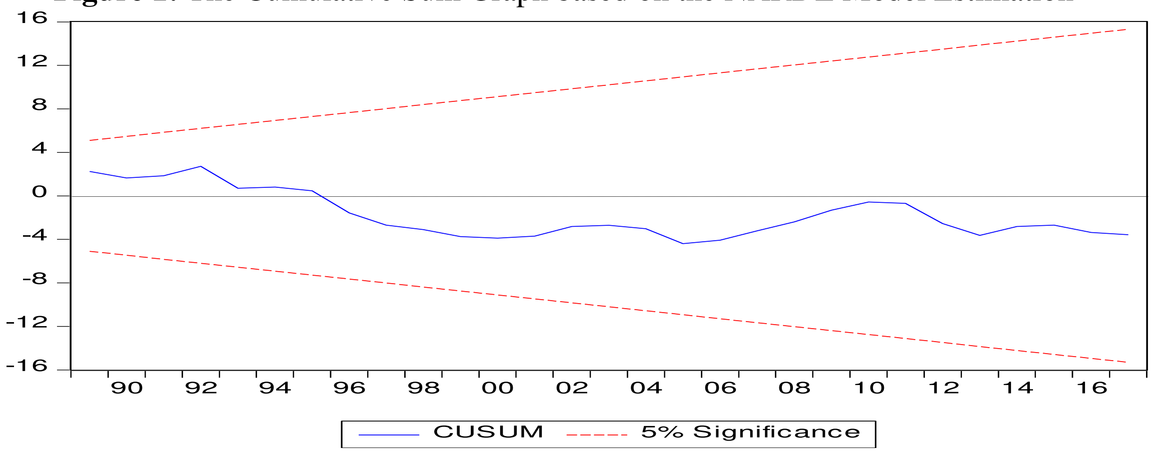
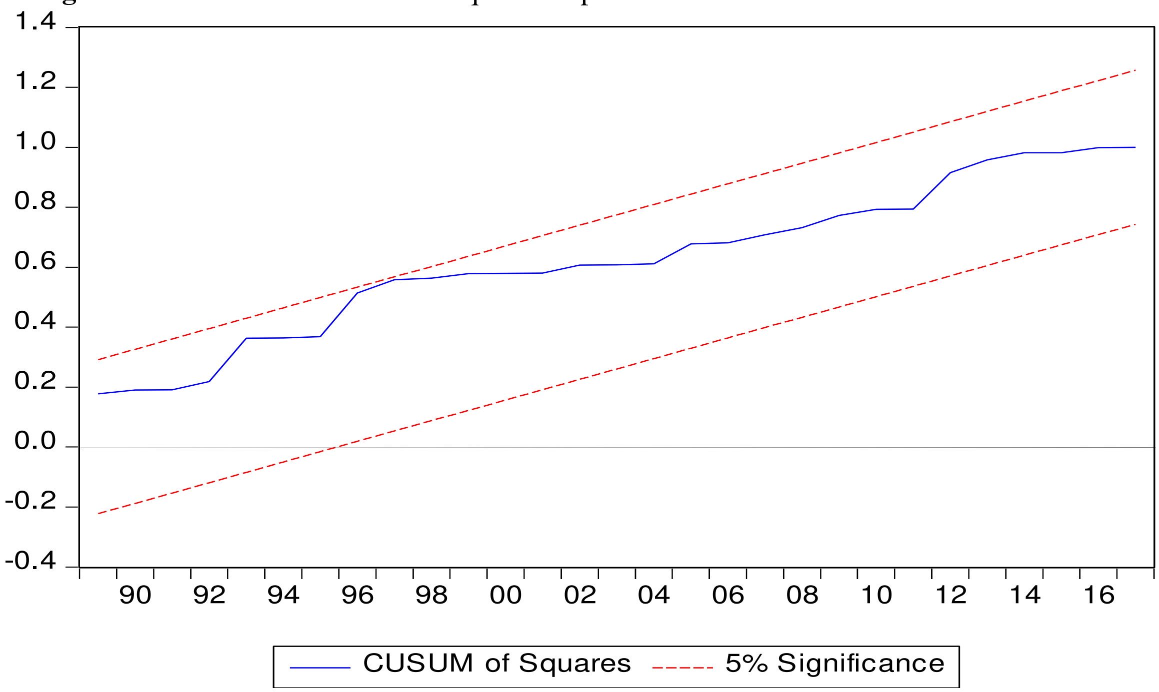
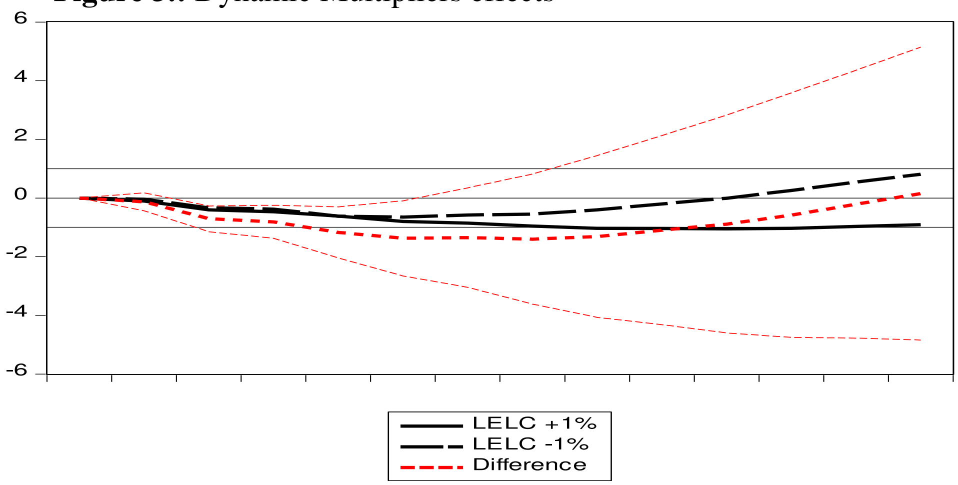


Figure 2: The Cumulative Sum of Square Graph based on the NARDL Model Estimation



In addition, we investigate the pattern of dynamic asymmetric adjustment of economic growth from its initial equilibrium to the new steady state in the long run shock, using the dynamic multiplier propose by Shin et al (2014). The Figure 3 reveals the dynamic effects of positive and negative changes in economic growth where electricity consumption responds more rapidly to a decrease in economic growth as compared to an increase. The asymmetric adjustment to positive and negative shocks at a given forecast respectively are shown by the positive (undotted line) and negative (dotted line) curves in Figure 3.

Figure 3.: Dynamic Multipliers effects



4.5 Asymmetric causality test

Having confirmed the validity of the estimated NARDL model, this paper proceed to test for the causal effects between electricity consumption and economic growth. Although the bounds test show the existence of long - and short run asymmetric relationship between electricity consumption and economic growth, it does not reveal the direction of causality, the implications of which can be of profound interest to policy makers. For this purpose, we use the asymmetric causality test which was proposed by Hatemi-J (2012b) to determine the causal links the two variables of interest. In this regard, the positive and negative shocks is assumed to have different Granger - causal impacts in the asymmetric causality test. In order to explain the asymmetric causality relation, let us assumed that our focus is on testing for causal nexus of two integrated variables such as x_{1t} and x_{2t}. The variables are first defined as the following random walk process:

$$x_{1t} = x_{1t-1} + \varepsilon_{1t} = x_{10} + \sum_{i=1}^{t} \varepsilon_{1t} \text{ and } x_{2t} = x_{2t-1} + \varepsilon_{2t} = x_{20} + \sum_{i=1}^{t} \varepsilon_{2t}$$

where t = 1, 2, …T, x_{10} and x_{20} are the constants that take initial values and ε_{1i} and ε_{2i} are the white noise error terms. Hatemi-J defined positive and negative shocks respectively as the following:

$\varepsilon_{1i}^{+} = \max\,(\varepsilon_{1i}, 0)$, $\varepsilon_{2i}^{+} = \max\,(\varepsilon_{2i}, 0)$, $\varepsilon_{1i}^{-} = \min\,(\varepsilon_{1i}, 0)$, $\varepsilon_{2i}^{-} = \min\,(\varepsilon_{2i}, 0)$. Therefore one can express $\varepsilon_{1i} = \varepsilon_{1i}^{+} + \varepsilon_{1i}^{-}$ and $\varepsilon_{2i} = \varepsilon_{2i}^{+} + \varepsilon_{2i}^{-}$. Due to this definition ε_{1i} and ε_{2i} can be defined as: $x_{1t} = x_{1t-1} + \varepsilon_{1t} = x_{10} + \sum_{i=1}^{t} \varepsilon_{1i}^{+} + \sum_{i=1}^{t} \varepsilon_{1i}^{-}$, similarly $x_{2t} = x_{2t-1} + \varepsilon_{2t} = x_{20} + \sum_{i=1}^{t} \varepsilon_{2i}^{+} + \sum_{i=1}^{t} \varepsilon_{2i}^{-}$. Finally, the positive and negative shocks of each variable can be defined in a cumulative form $x_{1t}^{+} = \sum_{i=1}^{t} \varepsilon_{1i}^{+}$, $x_{1t}^{-} = \sum_{i=1}^{t} \varepsilon_{1i}^{-}$ and $x_{2t}^{+} = \sum_{i=1}^{t} \varepsilon_{2i}^{+}$, $x_{2t}^{-} = \sum_{i=1}^{t} \varepsilon_{2i}^{-}$. It is important to mention that each positive as well as negative component has a permanent impact on the variables in question.

In what follows, we specify the step to testing the causal relationship between these components. Here we focus only on the case of testing for causal relationship between positive cumulative shocks. Assuming that $x_t^{+} = x_{1t}^{+}, x_{2t}^{+}$, then the test for Granger causality can be implemented by using the following vector autoregressive model of order *p*, VAR *(p)*:

$$x_t^{+} = \gamma + A_1 x_{t-1}^{+} + \ldots + A_p x_{t-1}^{+} + \mu_t^{+}$$

where x_t^{+} is the 2×1 vector of variables, γ is the 2×1 vector of intercepts, and μ_t^{+} is a 2×1 vector of residuals terms. The matrix A_r is a 2×2 matrix of parameters for lag order $r(r = 1, \ldots p)$. To select appropriate lag order (p) we used information criterion suggested by Hatemi-J which is defined as follows:

$$HJC = \ln\left(\left|\hat{\Omega}\right|\right) + j\left(\frac{n^2 \ln T + 2n^2 \ln(\ln T)}{2T}\right), \quad j = 1, \ldots, P$$

Where $\left|\hat{\Omega}\right|$ is the determinant of the estimated variance - covariance matrix of the residuals in the VAR model based on lag order j; n is the number of equations in the multivariate model, and T is the sample size. After determining the optimal lag order, we proceeded to test the following null hypothesis:

H_0: the row ω, column k element in A_r equals zero for r = 1, . . ., p.

In defining a Wald test in compact form for testing the above hypothesis, we make use of the following denotations:

$X = \left(x_1^{+}, \ldots, x_T^{+}\right)(n \times T)$ matrix

$D=\left(\gamma, A_1,\ldots, A_\rho\right)\left(n\times(1+np)\right)$ matrix

$$\begin{bmatrix} 1 \\ x_t^{+} \\ x_{t-1}^{+} \\ \cdot \\ \cdot \\ \cdot \\ x_{t-\rho+1}^{+} \end{bmatrix}\left((1+np)\times 1\right) \text{ matrix, } \; t=1,\ldots,T$$

$Z:\left(Z_0,\ldots,Z_{T-1}\right)\left((1+np)\times T\right)$ matrix

$\delta:\left(\mu_1^{+},\ldots,\mu_T^{+}\right)\left(n\times T\right)$ matrix

From the above we can define the VAR$\left(p\right)$ model in a compact form as:

$$X=Dz+\delta$$

In the above case, the null hypothesis of non-Granger causality, $H_0 := C\beta = 0$ is tested by the following test method:

$$Wald=(C\beta)'\left[C((z'z)^{-1}\otimes S_u)C'\right]^{-1}(C\beta),$$

Estimate of non-granger causality to be provided later

5. Conclusion and Policy Implication

This study examined the relationship between electricity consumption and economic growth along with investment and inflation in Nigeria in the period 1971-2017. The nonlinear Autoregressive Distributed Lag (NARDL) framework is utilized to allow for the exploration of possible asymmetric effects in both the long- and short-run time horizons using the nonlinear and asymmetric ARDL cointegration approach developed by Shin et al. (2014). First, our results from nonlinear ARDL bounds test show the existence of long- and short run asymmetric relationship between electricity consumption and economic growth. Second, the output of NARDL estimates show that positive changes in electricity consumption has no effect on economic growth, while negative changes in the electricity consumption has a significant positive long-run effect on economic growth. Specifically, in the long run, decline in electricity (negative changes) has a reducing impact on economic growth. Third, with the dynamic multipliers, we are able to establish the pattern of after-shock (positive/negative) adjustments from an initial long-run equilibrium position to a new long-run equilibrium position. This again confirmed the asymmetric nature of adjustment dynamics. Lastly, the dynamic effects of positive and negative changes in economic growth show that electricity consumption responds more rapidly to a decrease in economic growth as compared to an increase.

The policy implication that emerges from the study is that policy makers (the government) should ensure that electricity improves in order to avoid reduction in economic growth that could be associated with decline in electricity consumption. In order word, to cope with the perceived increase in Nigeria's GDP reported in recent time, electricity generation capacity must increase.

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