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The Dynamics of Electricity Demand and Comsumption in Nigeria: Application of the Bounds Testing Approach

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Abstract: Clear insights about the dynamic nature of electricity demand and consumption is essential for capacity additions, investments and effective optimal energy policies. This paper provides background analysis of electricity demand and consumption trends in Nigeria, with the key determinants of electricity demand and the investment requirements clearly highlighted. Further, the paper utilizes the bounds testing approach to empirically investigate the dynamics of electricity demand and consumption in Nigeria between 1970 and 2008. The results show that real GDP per capita, population and industrial output significantly drives electricity consumption in the long-run and short-run while electricity price is not a significant determinant. In the short-run, industrial output has a crowding out effect on the demand for electricity. The results are robust because the parameter estimates are stable over the estimation period. These results imply that income per capita is the major determinant of electricity demand, and therefore, deregulated pricing of electricity products, will ensure efficient product and resource allocation in Nigeria to reflect the observed income inelasticity for electricity products JEL Classification: C22; C32; Q41; Q42; Q43.

Key words: Bounds testing, cointegration, electricity consumption, Nigeria

INTRODUCTION

In recent times, the interest of mainstream energy economists, researchers and policy makers have been rekindled in modelling the determinants of energy demand functions within the context of emerging and developing countries. Emphasis has shifted to electricity as an energy input with the economic importance of stimulating socio-economic and technological development in an economy. Equally important is the need to obtain accurate estimates of electricity demand parameters for the purpose of forecasting, demand management and policy analysis.

In modelling the electricity demand function, concentration has centred on economic factors, mainly electricity prices and real income, while demographic factors like population, urbanization and environmental factors like climatic condition are often included as additional explanatory variables. In general, the dynamics of electricity demand and consumption are known to exhibit seasonality, mean-reversion, high volatility and spikes. These special characteristics of electricity products, necessitates the use of special models for the estimation and forecasting of these variables (Chuku and Effiong, 2011). Hence, the motivation for this study is to examine the dynamics of electricity demand and consumption in Nigeria, taking cognisance of the special characteristics of electricity consumption in an emerging and developing economy like Nigeria.

The demand for electricity in Nigeria is squarely for industrial, commercial and residential purposes. Figure 1 provides the trend of electricity consumption along with its disaggregated components. By visual inspection, electricity consumption by the residential sector has dominated other sectors since 1978, while the industrial sector's demand has witnessed continuous downward trend. The fall in the industrial sector's demand for electricity can be attributed to inadequate power supply which has forced manufacturers to resort to privately generated electricity for powering their production processes. Given the recent reforms embarked on by government to revamp electricity supply in Nigeria, it becomes important to model the key drivers of electricity demand in Nigeria in order to obtain empirical insights for electricity demand and supply projection and policy analysis.

The empirics on the demand for electricity consumption has mostly been analyze at a disaggregated level, focusing on the residential demand (Halicioglu, 2007; Ziramba, 2008; De Vita *et al*., 2006) with the inclusion of structural and demographic factors such as population, urbanization, climatic conditions along with economic factors like real income and electricity price (tariff) which are identified as the primary determinants of electricity demand. The relevance of the results of such studies depends largely on the choice of variables, econometric methods, data frequency and a country's developmental stage. From the perspective of econometric

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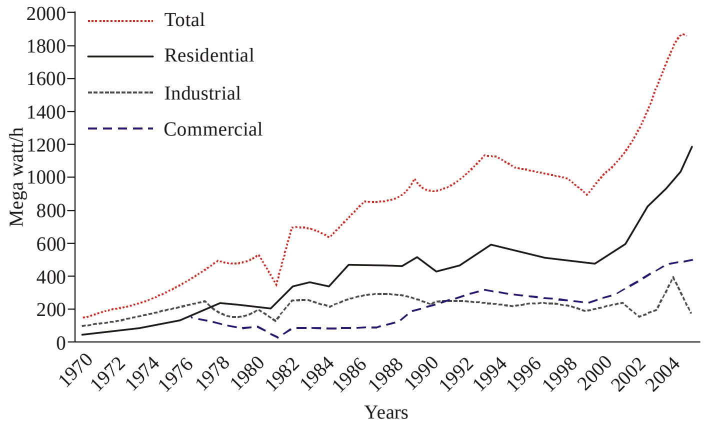

Fig. 1: Trend of electricity consumption in Nigeria (1970-2005), CBN Statistical Bulletin (2009)

methods, earlier studies relied on the use of the single and multivariate cointegration techniques of Engle and Granger (1987) and Johansen and Juselius (1990), respectively. A recent technique proposed by Pesaran *et al*. (2001) known as the bounds testing approach within an Autoregressive Distributed Lag (ARDL) framework has risen to prominence due to its superior advantages over previous techniques.

The objective of this study is to decouple the dynamics of electricity demand and consumption in Nigeria during the period 1970 to 2008. The decoupling exercise is done on the basis of identified key demand drivers peculiar to Nigeria. The exercise is achieved by adopting the methodological contribution of Pesaran *et al*. (2001) which involves the bounds testing approach to cointegration to investigate the existence of a long-run relationship as well as estimate the income and price elasticities both for the long-run and short-run dynamics. Also, the parameter stability tests of Brown *et al*. (1975) are implemented to ascertain the stability of the parameters in the electricity consumption function.

Electricity consumption patterns in Nigeria: Electricity consumers in Nigeria are classified into three major groups namely: residential sector, commercial sector and street lighting, and industrial sector. In most countries, industrial sector constitutes the largest consumer of electricity followed by residential sector and then commercial sector and street lighting. Based on available data, the observed pattern in Nigeria shows the reverse. Appendix 1 shows electricity consumption of the different sectors. The table reveals that except for the periods between 1970 and 1977 where industrial sector was leading in electricity consumption, residential sector had remained the largest consumer of electricity in Nigeria.

It is also observed that for many years now, electricity consumption by industrial sector has not only decreased but had being diminishing while the electricity consumption by residential sector is growing rapidly. Thus, there is a decreasing trend in industrial sector consumption of electricity and increasing trend in residential sector consumption of electricity. As shown in the Table 2, in 1970 industrial sector's consumption of electricity was 62.9% of the total electricity consumed in the country whereas residential sector's consumption of electricity accounted for only 37.1%. But in 1980 and 1990 industrial sector's consumption of electricity fell drastically to 37.2 and 25.6%, respectively while residential sector's consumption of electricity rose to 45.3 and 50.2%, respectively.

Electricity consumption by industrial sector continues to fall while the residential sector's consumption keeps on rising. The industrial sector's consumption of electricity was 22.0 and 21.8% in the year 2000 and 2004, respectively whereas residential sector's consumption of electricity rose to 51.0 and 51.4%, respectively. It is also observed that the commercial sector and street lighting consumption of electricity had been growing too, though not as rapid as residential sector's consumption of electricity. By all indications, residential sector is the largest electricity consumer in Nigeria. It is followed by the commercial sector and street lighting and then, the industrial sector (Ekpo, 2010).

The decreasing trend in electricity consumption by industrial sector is attributed to the persistent irregular and inadequate power supply in the country. The erratic and unreliable power supply in the country has compelled industrial sector into self generation of electricity through acquisition of private generating plant thereby reduce their dependence on public electric power supply. To most industrial firms in Nigeria, electricity generated from their private generating plants serves as the major source of electricity supply while electricity supply from public electric power source is use as a back-up. Ekpo (2010) reports that in a survey of Nigerian firms in the 1980s, about 90% of the firms had their own private generators.

The World Bank survey of Nigerian firms in the year, 2002, shown in Table 2 is quite revealing. It shows that 95.7, 98.2 and 98.2% of business firms located in the north, east and south of Nigeria respectively owned private generators. In average, about 97.1% of business firms located in Nigeria owned and operate private generator.

The persistent low capacity utilization in manufacturing industries in Nigeria also contributes to a decrease in industrial sector consumption of electricity. There had been a steady fall in capacity utilization of industrial sector since 1980s. The capacity utilization which was 85.2% in 1970 gradually declined to 38.8% in 1986. There was a modest increase to 45.8% in 1989, after which it fell to 29.3% in 1995. Though there have been gradual marginal increase from 1998, the capacity utilization in manufacturing industries had remained below 50%. The continuous low capacity utilization has suppressed demands for electricity by industrial sector.

Literature review: A considerable literature exist attempting to model and examine the determinants of energy demand functions within the context of developed and developing countries. Specifically, recent studies have focus on electricity as an important energy input for accelerating the growth process. Most of the studies on the determinant of electricity consumption have been considered at a disaggregated level with emphasis on the demand for residential electricity within the context of household production theory. Such studies have concentrated on non-African countries, for instance, Halicioglu (2007) for Turkey; Zachariadis and Pashourtidou (2007) for Cyprus; Narayan and Smyth (2006) for Australia; Galindo (2007) for Mexico; Holtedahl and Joutz (2004) for Taiwan; Filippini and Pachauri (2004) for India; Hunt *et al*. (2003) for the United Kingdom; Sa'ad (2009) for South Korea; Donatos and Mergos (1991) for Greece among others. A paucity of evidence exist for developing countries particularly for African countries except for studies such as De Vita *et al*. (2006) for Namibia; Ziramba (2008) for South Africa; and to the best of our knowledge, Babatunde and Shuaibu (2009) for Nigeria. However, an aggregated analysis that incorporates other uses of electricity such the industrial and commercial sectors to obtain robust estimates of electricity demand parameters for policy decision-making is considered pertinent with this paper filling the vacuum.

In modelling the determinants of electricity demand, a diversity of approaches have been adopted ranging from the simplest forms of a single variable such as real income (Dincer and Dost, 1997) to a collusion of other variables like real income and electricity price (Ziramba, 2008); real income, electricity price, price of substitutes (Al-Faris, 2002; Narayan and Smyth, 2006); real income, electricity price, population growth, structural changes and efficiency improvement (Lin, 2003; Sa'ad, 2009). Aside, from the important variables like real income, electricity price, population growth, other studies such as Nasr *et al*. (2000), Beenstock *et al*. (1999), Donatos and Mergos (1991) have introduced a temperature variable to capture climatic conditions in their model.

Primarily, the demand for electricity is influenced by two basic variables, namely, income and electricity prices (Sa'ad, 2009). The income level which proxies the level of economic activity as well as standard of living is perhaps the most important determinant of electricity demand. The demand for electrical goods and services (e.g., television, refrigerators, air-conditioners etc.) increases as income rises. This puts significant pressure on the demand for electricity for their usage. This implies that a positive correlation exist between income and electricity consumption. The price of electricity is another factor affecting electricity consumption. Higher prices causes substantial reduction in the demand for electricity particularly in the short-term while in the long-term, it stimulates the purchase of more efficient alternative energy appliances.

Other notable factors include population, prices of energy substitutes, urbanization, climatic condition and the level of industrialization. Population is an important structural factor which affects the level of electricity consumption in an economy. The relationship is precisely positive as higher population is expected to increase the demand for electricity. The industrial base of an economy puts significant pressure on the demand for electricity. As rapid industrial growth intensifies, electricity is consequently demanded for the powering of production equipments and machineries for enhanced capacity utilization. Urbanization and climatic condition are rarely incorporated except in the case data availability. The introduction of prices of energy substitutes such as natural gas and petroleum products depends on their relative intensity to electricity. In Nigeria, only a small fraction of the population especially in the urban areas has access to such alternative energy sources. Thus, only four variables, namely, real income, electricity prices, population and the industrial sector's output are utilized for the analysis.

Several estimation approaches have been considered in investigating the demand for energy functions. This ranges from the univariate cointegration approach of Engle and Granger (1987) to the multivariate cointegration procedures of Johansen (1988) and Johansen and Juselius (1990). A recent development known as the bounds testing approach proposed by Pesaran *et al*. (2001) has become popular among economic modellers of energy demand functions due to its advantages over other approaches which includes: i) testing for the existence of a long-run relationship between the variables in levels irrespective of the order of integration underlying the regressors, be they purely I(0), purely I(1) or fractionally integrated; ii) the simultaneous estimation of both long-run and short-run parameters; iii) adaptability to finite sample sizes. (Choong *et al*., 2005). Given its superiority, the bounds testing procedure has been adopted by Halicioglu (2007), Narayan and Smyth (2006), Ziramba (2008) and Babatunde and Shuaibu (2009) in modelling the demand for residential electricity. This paper follows suit by adopting the ARDL approach in the analysis of the dynamics of electricity consumption in Nigeria.

Determinants of electricity demand: In general, it is widely accepted that the demand for electricity is determined by two factors; the household's income and electricity prices (tariffs). However, there are some other factors that are also important factors determining the demand for electricity, these factors include efficiency improvement, structural changes and household's lifestyles. It can therefore be argued that, when estimating energy demand functions, it is instructive to consider all of these factors to avoid producing biased estimates of price and income elasticities.

Household's income: Household's income is most important determinant of electricity consumption. Increase in income and its impact on living standards is the main driving force of electricity consumption. As a household's income increases, people tend to demand more entertainment, comfort, and convenience that will accelerate the ownership of televisions, refrigerators, air-conditioners, and heaters as well as other household appliances. These will increase the energy required for cooking, heating, and lighting. Many studies show that there should be significant and stable positive correlation between household's income and electricity consumption.

Electricity prices: As with the household's income, electricity price is another important factor affecting electricity income. High electricity price may cause households to use less energy in the short-term. In the long-term, this will stimulate the purchase of more efficient appliances whose end product is expected to bring about a substantial reduction in electricity use at a given prices. Accord ingly, it is expected that there exist a negative correlation between electricity prices and household's consumption of electricity.

Efficiency improvement: Efficiency improvement is also another important determinant of household's demand for electricity. Individual households demand for electricity is a derived demand, it is derived from the demand for services like heating and cooling obtained from using appliances and equipment (such as heaters and air-conditioners). Hence, the utility obtained from electricity-using equipment and appliances depends on the technology embedded in such equipment and appliances. In the short-term, since individual households are tied to fixed equipment and appliances, they are constrained in the services they obtain from using them. However, in the long-run, due to progress in knowledge such as the learning of new demand management including timing appliances for switching thermostats, etc on or off this will bring about an appreciable increase in energy efficiency. Furthermore, the modification of existing appliances and introduction of new ones in to the market will change the technical characteristics of the appliance and equipments which can also bring about energy efficiency, thereby reducing overall electricity consumption in the long-run.

Structural factors: Changes in economic structure could bring about a substantial increase (or decrease) in electricity consumption. Factors such as size of households, age distribution and climatic condition of an area will have impact on the household's consumption of electricity. Gladhart *et al*. (1986) found that socio demographic factors such as family size, age distribution, and the number of wage earners in the household were significant in determining the energy use. Household structure defines the living dimensions in a particular house; larger households use more appliances and energy than smaller households. However, on a per capita basis, smaller households tend to use more energy than larger ones (Schipper *et al*., 1989). Likewise, age distribution also will have some influence on household energy consumption; people of old age and perhaps retirees tend to remain in their homes and use more energy for heating and cooling than young and middle-aged people who go to work or school daily.

Similarly, climate also plays an important role in residential energy consumption. It is well known that people tend to use more electricity and fuel to warm their homes during the winter and air conditioning during the summer season. Population growth and living standard are also among the structural factors that can affect the demand for electricity. Higher population growth is expected to increase electricity consumption. Population growth in Nigeria has been moderate over the period of the study. However, because of the majority of the population in Nigeria lives in urban areas, with relatively high standard of living, these factors still have substantial impact on the electricity consumption in Nigeria

Lifestyles: Similarly, household's lifestyles can also bring about a significant increase (or decrease) in household electricity consumption. A household may decide to change from using fire-wood sources of energy to more convenient and environmentally friendly electric cookers and heating systems. For example, in many countries, urbanization and increased family income have resulted in a shift from fire wood and kerosene to other forms of energy such as electricity and gas; this is known as "stepping-up-the-fuel ladder". Invariably, this will also bring about a substantial increase in a household's electricity and gas consumption. While household income and electricity tariffs play a fundamental role in shaping the residential demand for electricity, the effects of improve efficiency as well as structural factors and household's lifestyles are an equally important determinant of a household's energy consumption. The price and income elasticities can be used to show the impact of changes in households' incomes and electricity prices on electricity consumption. However, the effects of energy efficiency and the structural factors can only be approximated by the slope of the underlying energy demand trend.

Demand forecasts of electricity requirement in Nigeria: Projection of the demand for electricity is based on a fairly disaggregated bottom-up approach built on a number of policy variables. This approach, which is transparent and requires fewer assumptions and data than a detailed approach, involves estimating the demand for electricity based on sectoral projections, that is, projections for electricity demand in the four major end-use sectors consisting of residential, industrial, commercial, and agricultural sectors. This approach to demand projections is also different from the traditional approach based essentially on adaptive expectations, whereby the past is used as a platform to project into the future (Ibitoye and Adenikinju, 2006).

The traditional approach suffers from some deficiencies. First, it assumes the availability of correct and adequate historical data from which the future could be inferred; this could be a major handicap in the case of Nigeria. Secondly, there is the possibility of transferring past inefficiencies in the energy system into the future. Thirdly, it assumes that parameters of historical relationships will not change.

However, in an economy like that of Nigeria, with significant suppressed demand due to non-availability or inadequate supply, the past might not provide the appropriate anchor for the future, especially when there is a major policy drive to reduce the demand-supply gap.

A summary of the major drivers used for projecting the demand for electricity in Nigeria is presented in Ibitoye and Adenikinju (2006), using two different economic growth scenarios, i.e. upper-middle income and lower-middle income. Four major motivations drive or provide the ingredients for increasing supply in Nigeria. They include: the desire to attain the status of one of the 20 largest economies in the year 2020, the desire to transform from a low to a middle income country and the desire to achieve the Millennium Development Goals by 2011.

Investment requirements in Nigerian electricity: One major issue for consideration is the investment stream needed to provide sufficient electricity supplies in Nigeria, is public private partnership arrangements. Investments are particularly required in three specific streams, viz., capital expenditure (CAPEX), operating expenditure (OPEX), and electricity transmission and distribution costs lumped with natural-gas pipeline expansion costs, (TRXEX) (Ibitoye and Adenikinju, 2006).

The common argument is that risk-averse investors who cover their production with short-term contracts will provide for less generation capacity than risk-lover investors in the electricity markets. Investors typically only have imperfect information about future demand and supply (Neuhoff and Vries, 2004). To calculate their revenues, investors need to anticipate future electricity prices which are difficult to forecast.

MATERIALS AND METHODS

The ARDL model: Evaluating empirically the determinants of electricity consumption in Nigeria with particular emphasis on establishing the existence of a long-run relationship, we adopt the Autoregressive Distributed Lag (ARDL) model, alternatively called the bounds testing approach as proposed by Pesaran *et al*. (2001).

The preference for the bounds testing approach over traditional bivariate cointegration techniques (Engle and Granger, 1987; Johansen, 1988; Johansen and Juselius, 1990) is predicated on four fundamental reasons. First, the ARDL model can be estimated by Ordinary Least Squares (OLS) once the model lag order is identified. Second, the long-run and short-run parameters of the model can be estimated simultaneously. Third, pre-testing for unit roots is not required as the bounds test can be applied irrespective of the order of the integration of the regressors, be it purely I(0), purely I(1) or fractionally integrated. Fourth, the efficiency of the test is further enhanced particularly with small (finite) sample sizes.

Following Pesaran *et al*. (2001) as summarized by Choong *et al*. (2005) and adopted by Halicioglu (2007); Ziramba (2008) and Narayan and Smyth (2005), a general autorgressive model of order p, VAR(p), is constructed for the determinants of electricity consumption thus:

$$Z_t = \mu_0 + \delta t + \sum_{i=1}^{p} \phi_i Z_{t-1} + \varepsilon_t, \qquad t = 1,2.....,T \qquad (1)$$

with μ_0 is (k+1) vector of intercepts and denoting a (k+1) vector of trend coefficients. The corresponding Vector Error Correction Model (VECM) for Eq. (1) is derived as:

$$\Delta Z_t = \mu_0 + \delta t + \lambda Z_{t-1} + \sum_{t=1}^{p} \gamma_i \Delta Z_{t-1} + \varepsilon_t \qquad (2)$$

where; λ and γ are vector matrices that contain the long-run multipliers and short-run dynamic coefficients of the VECM respectively. Z_τ is a vector of x_τ and y_τ variables, respectively. y_τ is the regressand denoted as LEC_τ and x_τ = [$LEPR_\tau$, $LPCI_\tau$, $LPOP_\tau$, $LINDO_\tau$] is a vector matrix of a set of regressors. LEC and LEPR are per capita electricity consumption (KW) and electricity prices in naira per megawatts (N/MWh) while LPCI is real GDP per capita. LPOP and LINDO are total population and industrial output, respectively. All variables are transformed to their logarithmic form. As a condition, y_τ must be an I(1) variable while x_τ regressors can either be I(0) and I(1). ε_τ is a stochastic error term. Assuming unrestricted intercepts and no trends, Eq. (2) becomes an unrestricted error correction model (UECM) as:

$$\Delta Z_\tau = \mu_0 + \lambda Z_{\tau-1} + \sum_{i=1}^{p} \gamma_i \Delta Z_{\tau-1} + \varepsilon_\tau \qquad (3)$$

Decomposing into x_τ and y_τ, Eq. (3) be stated in a reduced form as:

$$\begin{aligned}\Delta y_\tau &= C_{y0} y_{\tau-1} + \beta_{xx} x_{\tau-1} \\ &\quad + \sum_{i=1}^{p} \gamma_i \Delta y_{\tau-1} + \sum_{i=0}^{p} \gamma_i \Delta x_{\tau-1} + \varepsilon_\tau \end{aligned} \qquad (4)$$

Incorporating the variables of interest, the UECM of Eq. (4) becomes thus:

$$\begin{aligned}\Delta LEC_\tau &= C_0 + \beta_1 LEC_{\tau-1} + \beta_2 LEPR_{\tau-1} \\ &\quad + \beta_3 LPCI_{\tau-1} + \beta_4 LPOP_{\tau-1} + \beta_5 LINDO_{\tau-1} \\ &\quad + \sum_{i=1}^{p} \gamma_1 \Delta LEC_{\tau-i} + \sum_{i=0}^{p} \gamma_2 \Delta LEPR_{\tau-i} \\ &\quad + \sum_{i=1}^{p} \gamma_3 \Delta LPCI_{\tau-i} + \sum_{i=0}^{p} \gamma_4 \Delta LPOP_{\tau-i} \qquad (5) \\ &\quad + \sum_{i=0}^{p} \gamma_5 \Delta LINDO_{\tau-i} + \varepsilon_\tau \end{aligned}$$

where Δ is the first-difference operator, β_i are long-run multipliers, γ_i are short-run dynamic coefficients and C_0 is the intercept (drift).

ARDL testing approach: The testing procedure of the ARDL bounds test is performed in three steps. First, OLS is applied to Eq. (5) to test for the existence of a cointegrating long-run relationship normalized on LEC_τ based on the Wald test (F-statistics) for the joint significance of the lagged levels of the variables (i.e., H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$) as against the alternative (H_1: $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq 0$). The computed F-statistic is then compared with the non-standard critical bounds values as reported in Pesaran *et al*. (2001). The optimal lag length for estimating Eq. (6) is selected using the Schwarz Bayesian Criterion (SBC).

The lower and upper bounds critical values assumes that the regressors are purely I(0), purely I(1), respectively. If the computed F-statistic lies below (above) the lower (upper) critical values, the null hypothesis of no cointegration is accepted (rejected). The test is inconclusive if the computed F-statistic lies in between the lower and upper critical values.

Once cointegration is established, the second step involves estimating the long-run ARDL model for LEC_τ as:

$$\begin{aligned} LEC_\tau &= C_0 + \sum_{i=1}^{p} \beta_1 LEC_{\tau-i} \\ &\quad + \sum_{i=0}^{p} \beta_2 LEPR_{\tau-i} + \sum_{i=0}^{p} \beta_3 LPCI_{\tau-i} \qquad (6) \\ &\quad + \sum_{i=0}^{p} \beta_4 LPOP_{\tau-i} + \sum_{i=0}^{p} \beta_5 LINDO_{\tau-i} + \varepsilon_\tau \end{aligned}$$

The final step involves estimating an Error Correction Model (ECM) as derived from Eq. (6) to obtain the short-run dynamic parameters as specified below:

$$\begin{aligned} \Delta LEC_\tau &= C_0 + \sum_{i=1}^{p} \gamma_1 \Delta LEC_{\tau-i} \\ &\quad + \sum_{i=0}^{p} \gamma_2 \Delta LEPR_{\tau-i} + \sum_{i=0}^{p} \gamma_3 \Delta LPCI_{\tau-i} \qquad (7) \\ &\quad + \sum_{i=0}^{p} \gamma_4 \Delta LPOP_{\tau-i} + \sum_{i=0}^{p} \gamma_5 \Delta LINDO_{\tau-i} \\ &\quad + \eta ecm_{\tau-1} + \varepsilon_\tau \end{aligned}$$

Data sources: The time series data for each variable covering the period of analysis (1970-2008) were obtained as follows. Data on electricity consumption per

Table 1: Unit roots tests

	ADF statistic		PP statistic		
Variables	Levels	1st difference	Levels	1st difference	Remarks
LEC	- 2.42572	- 6.19211***	- 2.55944	- 8.30487***	I(1)
LEPR	- 1.39538	- 4.93817***	- 1.39538	- 4.98686***	I(1)
LPCI	- 1.36856	- 2.76200*	- 1.11654	- 2.71310*	I(1)
LPOP	- 4.42605***	-	- 2.79828*	-	I(0)
LINDO	- 2.85977*	- 5.87067***	- 7.05732***	- 5.87008***	I(0)/I(1)

***, **, *: denotes the rejection of the null at 1, 5 and 10% significance level; Critical values are MacKinnon (1996) one sided p-values

capita (KW/h), real GDP per capita and population were sourced from World Development Indicators while industrial output data was retrieved from the 50 years Special Anniversary Edition of CBN Statistical Bulletin (2009). Data on electricity prices was sourced from various issues of the Annual Reports and Accounts of National Electric Power Authority (NEPA). The data series ends at 2004 and was subsequently updated with statistics from the Nigerian Regulatory Electricity Commission.

RESULTS AND DISCUSSION

Unit roots test: Before applying the ARDL bounds test, the stationarity properties of all variables are examine to ascertain their respective orders of integration. The rationale behind the unit roots test is to avoid spurious results due to the presence of an I(2) series. The bounds test is based on the assumption that the variables are $I(0)$ or $I(1)$ series. The presence of an $I(2)$ series renders the computed *F*-Statistic invalid thereby crushing the ARDL procedure. Hence, pre-testing for unit roots remains pertinent to the analysis. The Augmented Dickey-Fuller (ADF) test was applied on each variable while the Phillips-Perron (PP) test was used for confirmatory analysis with the results presented in Table 1.

The results show that the logs of per capita electricity consumption electricity price and GDP per capita are integrated at order one, $I(1)$, after first differencing. The log of population is stationary at levels implying an integration of order zero, I(0); while the log of industrial output is both stationary at levels and first difference. Overall, both test report similar results while confirming the absence of an $I(2)$ series, thus indicating the suitability of the variables for the ARDL bounds test.

Bounds test for cointegration: In the first step of the ARDL testing procedure, Eq. (5) is tested for a cointegrating long-run analysis with normalization on the log of per capita electricity consumption. To select the appropriate lag length for the first differenced variables, we adopted a general-to-specific approach using an unrestricted VAR by means of Schwarz Bayesian Criterion (SBC). For brevity, the results of the lag selection are not reported, however, a maximum of 2 lag was used. As argued by Pesaran and Pesaran (1997), variables 'in first difference are of no direct interest' to the bounds cointegration test. Hence, any result that supports cointegration in at least one lag structure provides evidence for the existence of a long-run relationship. The calculated F-statistic together with the critical bounds values are reported in Table 2.

Table 2: Bounds test for cointegration

Panel A				With Intercept and no deterministic trend *F*-statistics		
F_{LEC}(LEC/LEPR,LPCI,LPOP,LINDO)				4.7846**		
Panel B	1%		5%		10%	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
	3.74	5.06	2.86	4.01	2.45	3.52

Asymptotic critical bounds values are obtained from Table CI case III: Unrestricted intercept and no trend for $K = 4$ from Pesaran *et al*. (2001); **: denotes 5% significance level. The number of regressors is 4

Table 3: Long-run and short-run estimates

Panel A: Long-run Estimates

Dependent Variable: LEC_τ

C	$LEPR_\tau$	$LPCI_\tau$	$LPOP_\tau$	$LINDO_\tau$
-2.786	-0.449	0.587*	0.892**	0.176***
(-0.929)	(-0.287)	(1.977)	(2.496)	(4.355)

Panel B: Short-run estimates

Dependent Variable: ΔLEC_τ

C	$\Delta LEPR_\tau$	$\Delta LPCI_\tau$	$\Delta LPOP_\tau$	$\Delta LINDO_\tau$	$ecm_{\tau-1}$
-0.55	-0.233	0.228*	0.865**	-0.104**	-0.724***
(-2.229)	(-1.298)	(1.791)	(2.424)	(-2.303)	(-5.897)

$ecm = LEC_\tau + 0.449LEPR_\tau - 0.587LPCI_\tau - 0.892LPOP_\tau - 0.176LINDO_\tau + 2.786C$

Panel C: Short-run Diagnostics

$R^2 = 0.625$	F-stats= 10.36[0.000]***
$\chi^2_{norm} = 1.834[0.3997]$	$\chi^2_{auto}(1) = 2.612[0.116]$
$\chi^2_{hetero}(1) = 1.489[0.2112]$	$\chi^2_{reset}(1) = 0.796[0.379]$

***, **, *: denotes significance at 1, 5 and 10% level respectively. Δ is first difference operator. Figures in parentheses are t-ratios

The calculated value of the F-statistic (i.e., 4.7846) for the bounds test for cointegration exceeds the upper bound critical value of 4.01 at 5% level. Thus, the null hypothesis of no cointegration cannot be accepted and a long-run cointegrating relationship does exist. Based on the result in Table 2, we conclude that there is strong support for a long-run electricity demand relationship in the model for Nigeria.

Following the establishment of the existence of cointegration, Eq. (6) and (7) were estimated to obtain long-run and short-run dynamic estimates using an ARDL (1,0,0,0,0) with results presented in Table 3.

The result shows that the price elasticity of electricity price has a negative sign of 0.44 and 0.23 both in the long-run and short-run respectively though insignificant. This means that electricity consumption in Nigeria is price inelastic, while its insignificance can be attributed to government involvement in the electricity sector through regulation of electricity price. The income variable satisfied the a-priori expectation with an income elasticity of 0.58 in the long-run and is consistent with the theory that an increase in income will stimulate an increase in the demand for electrical goods and services. The magnitude is greater than the short-run income elasticity of 0.22 with both being statistical significant with the indication that electricity is income inelastic. This implies that electricity is a normal good with income policies likely to have stronger impact on electricity demand in the future.

The population parameter has a positively signed coefficient of 0.89 and 0.86 in the long-run and short-run respectively, and is also significant. This implies that higher population will increase the demand for electricity. Its magnitude exceeds that of other variables, hence, we deduce that population constitute a major driver of electricity consumption in Nigeria. This scenario is quite understandable given the current drive by government at various levels to link the hinterlands to the national grid. The demand for electricity in the industrial sector has a positive coefficient of 0.17 in the long-run and a negative value of 0.10 in the short-run with both being statistically significant. The short-run coefficient of -0.10 supports the thesis that manufacturers in the sector have resorted to alternative means of generating electricity for their production process due to the epileptic power supply in the country (Fig. 1). However, its significance indicates that the industrial sector still remains a major determinant of electricity consumption in Nigeria.

The error-correction term is 0.72 with the expected sign, suggesting that when demand is above or below its equilibrium level, consumption adjusts by approximately 72% within the first year to ensured full convergence to its equilibrium level. The statistical significance of the error-correction term confirms the bounds test for cointegration (Table 2) that a long-run equilibrium relationship exists between the variables. The goodness-of-fit for the short-run ARDL model is approximately 63% and satisfies the diagnostic tests for serial correlation, normality, heteroskedasticity, and functional form as reported in Panel C above.

Finally, to ensure that the models satisfy the stability test, we apply the cumulative sum of recursive residuals (CUSUM) and CUSUM of squares (CUSUMSQ) test proposed by Brown *et al.* (1975) to the residuals of the error-correction model. Figure 2 present plots of both CUSUM and CUSUMSQ test statistics that fall inside the critical bounds of 5% significance. This implies that the estimated parameters are stable over the period 1970-2008.

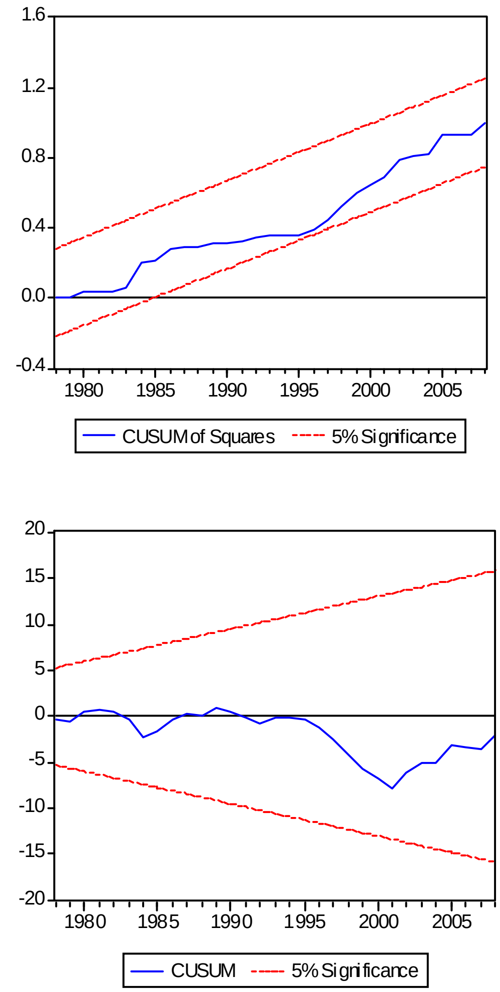

Fig. 2: Plot of CUSUM and CUSUMSQ for stability tests

CONCLUSION

The study investigated the dynamics of aggregate electricity consumption in Nigeria, using annual time series data over the period 1970-2008. The demand for electricity was modelled as a function of real GDP per capita, electricity price, population and industrial sector's output as identified in the literature. The study employed one of the most recent advances in time series econometrics, which is the bounds testing approach to cointegration, to ascertain the existence of a long-run equilibrium relationship for electricity demand in Nigeria; and also to estimate both the long-run and short-run dynamic estimates of the model. Further, parameter stability tests were conducted to validate the stability of the estimated coefficients over the period of analysis.

The findings of the study indicates that in the long-run, electricity consumption is positively and significantly influenced by income, population and industrial sector's output, while electricity price is insignificant though with the expected sign due to government regulation of prices. The income elasticity of 0.58 indicates that electricity is normal good which increases with income, while magnitude of the population parameter (i.e., 0.89) suggest that population drives the consumption of electricity more than other variables in the Nigerian case. The short-run dynamic estimates are lower than the long-run estimates and are equally significant except for electricity price. The negative sign of the industrial output parameter (i.e., -0.10) confirms that the sector's consumption of electricity declines in the short-run due to the use of alternatives means of generating electricity. The stability tests show that long-run aggregate electricity demand function is stable over the estimation period.

The policy implications drawn from the analysis are three-fold. First, government should undertake a guided process of liberalizing the electricity sector to allow new entrants into the market for competitiveness and improved efficiency as the insignificance of the electricity price variable justifies the seemingly gross inefficiency in the sector. Second, attempts at reducing electricity consumption through imposition of taxes will become fruitless; hence, emphasis on non-market policies like public enlightenment, enforcing energy efficiency standards will encourage electricity conservation and efficiency especially in the residential sector which is the largest consumer of electricity in Nigeria. Lastly, providing steady electricity supply is paramount for the country's quest towards industrialization, hence government should undertake a cogent approach towards reforming the electricity supply sector.

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Appendix 1: Electricity consumption (Mega Watts per h)

Year	Total consumption	Industrial	Total (%)	Commercial street lighting	Total (%)	Residential	Total (%)
1970	145.3	91.4	62.9	-		53.9	37.1
1971	181.1	114.9	63.5	-		66.2	36.5
1972	211.1	138.2	65.5	-		72.9	34.5
1973	232.7	146.1	62.8	-		86.6	37.2
1974	266.7	163.2	61.3	-		103.0	38.7
1975	318.7	200.4	62.9	-		118.3	37.1
1976	369.8	214.6	58.0	-		155.2	42.0
1977	435.7	253.0	58.1	-		182.7	41.9
1978	504.4	157.7	31.3	95.5	18.5	253.2	77.9
1979	460.1	160.3	34.8	77.9	16.9	221.9	48.2
1980	536.9	199.7	37.2	94.1	17.5	243.1	45.3
1981	335.9	121.0	30.2	21.3	21.3	193.6	48.4
1982	685.6	262.0	38.4	79.1	11.6	344.5	50.6
1983	696.7	254.4	36.5	84.3	12.1	358.0	51.4
1984	625.5	217.2	34.7	81.7	13.1	326.6	56.6
1985	717.4	259.8	36.2	85.6	11.9	472.0	54.9
1986	841.8	280.5	33.3	84.7	10.1	476.6	52.0
1987	852.9	294.1	34.5	90.2	10.6	468.6	53.6
1988	853.5	291.1	34.1	118.6	13.9	443.8	50.7
1989	976.8	257.9	26.4	195.3	20.0	523.6	48.5
1990	896.5	230.1	25.6	217.6	24.2	450.8	48.5
1991	946.6	253.7	26.8	254.1	26.8	459.3	51.9
1992	993.0	245.3	24.7	266.1	26.8	481.6	52.5
1993	1,141.40	237.4	20.8	311.6	27.3	592.4	51.9
1994	1,115.00	233.3	21.3	306.7	28.0	575.0	52.5
1995	1,050.90	218.7	20.3	279.6	26.0	552.6	51.3
1996	1,033.30	235.3	22.8	280.0	27.1	518.0	50.1
1997	1,009.60	236.6	23.5	264.5	26.2	508.3	50.3
1998	972.6	218.9	22.6	253.9	26.1	500.0	51.4
1999	883.7	191.8	21.7	236.8	26.8	455.1	51.5
2000	1,017.30	223.8	22.0	274.7	27.0	518.8	51.0
2001	1,104.70	241.9	21.9	298.3	27.0	568.5	51.1
2002	1,271.60	146.2	11.5	372.6	29.3	752.8	59.2
2003	1,519.50	196.0	12.9	417.9	27.5	905.8	59.6
2004	1,825.80	398.0	21.8	489.3	26.8	938.5	51.4

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