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Abstract
The Nigeria's electricity problem is not just one of quantity, but also of reliability and efficiency. The question of whether what is supplied represents the optimal supply is another issue. Thus, drawing from historical data, this study, therefore examined the optimal or desired electricity supply in Nigeria from 1980 to 2014 using partial adjustment model of electricity supply that is estimated in a fixed-effects OLS framework. The stationary properties of the series are explored using modified Ng-Perron unit root test. The results revealed that all the variables are I(1) process except electricity loss which is I(0). The ARDL Bound Testing approach to cointegration revealed an inconclusive evidence of long-run relationship among the variables of study. The finding indicates that actual electricity supply in Nigeria for the period under review has been less than the optimal level, except in 2014. The paper, therefore recommends that government should inject more funds/subventions into the power sector in order to complete the various power projects with state of the art technology and that adequate security measure should be put in place to protect electricity generation, transmission and distribution equipments from being vandalized.

Keywords: Optimal, electricity supply, partial adjustment model.
JEL Classification: C32, C50, C51, O13

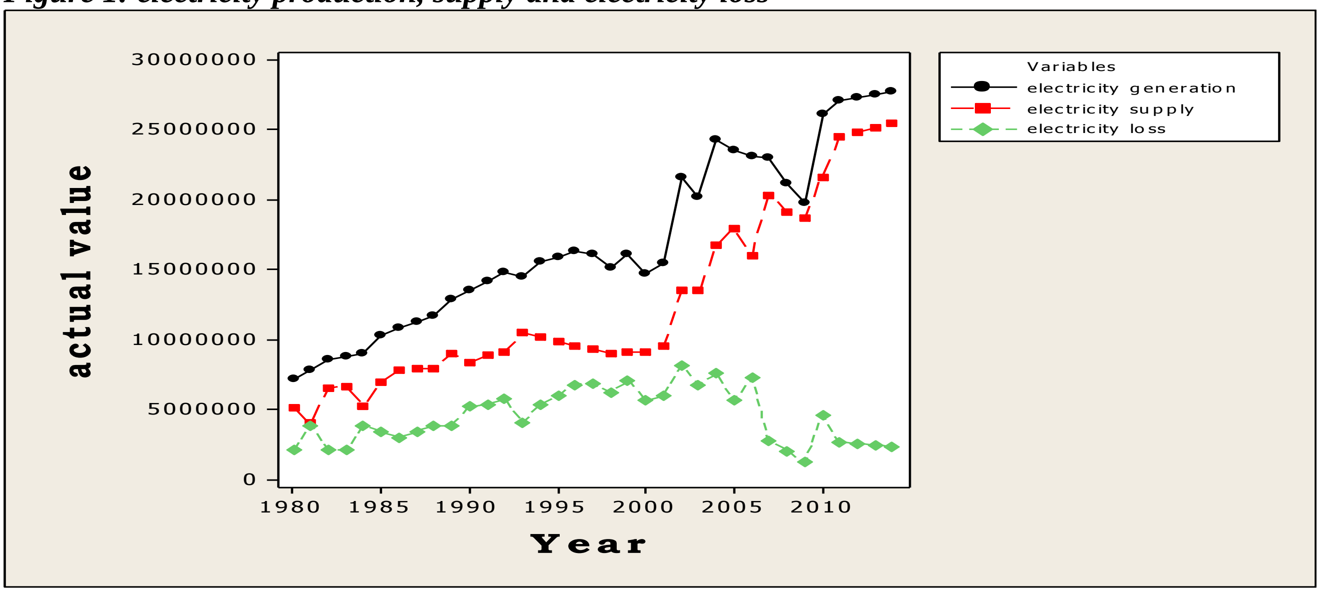
1. Introduction

Access to stable and secure energy is one of the key drivers of today's prosperity. Energy is a prerequisite for economic growth and human development. It is critical in fulfilling basic needs such as cooking, lighting, mobility, water pumping among others. Secure and stable access to energy has been identified as source of today's prosperity. Modern production will grand to halt without requisite energy infrastructure, as it is evident in most parts of the developing country. Hence, governments world over are committed to building energy infrastructure (Isaksson, 2010; Afaha, 2014). Isaksson (2010) argues that almost every country that is rich has become so through industrial development, although most of the industrialized countries are already focusing on services, rather than manufacturing. Compared with agriculture and services, manufacturing production is relatively energy-intensive, which implies that industrialization increases demand for energy and, thus, a need for adequate energy infrastructure. From this, the conclusion emerges that some countries are rich while others are not because the former have managed to ensure their access to energy by building infrastructure.

Nigeria has been battling with energy problem of enormous proportion. The power vacuum in the country is overwhelming. Evidence from a World Bank study suggests that Nigeria produced 124 KWh per year in 2010, this value does not compare with other African OPEC members such as Angola, with 238 KWh, and Libya, with 3360 KWh. The country's generating capacity, which stood at around 3500 MW in 2010, was well below the corresponding figure for the much-less-populous South Africa, which was approximately 47,000 MW (The Report Nigeria, 2012).

Currently, Nigeria produces about 40 KW per thousand people, according to government data. South Africa, which Nigeria surpassed in terms of overall GDP thanks to its April 2014 rebasing, produces 270 KW per thousand people, for example. India is at 145 KW, Brazil 530 KW and Indonesia 120 KW (The Report Nigeria, 2015). Electricity generation, transmission and distribution still account for less than one per cent of Nigeria's Gross Domestic Products [GDP], but fifty-four per cent of the share of Utilities (electricity and water supply) in the GDP. We document graphical evidence showing the electricity generation, electricity supply and electricity loss (transmission and distribution loss) using data from 1980 to 2014.

Figure 1: electricity production, supply and electricity loss



Source: the authors' computation based on data from WDI, (2016).

Though, electricity production and supply have been increasing over time, the supply has not met the ever increasing electricity demand by Nigerians, hence the high dependent on alternative electricity sources like back-up generators, solar power, biomass etc. Although there are no official statistics, estimates of generator sales from vendors, according to The Report Nigeria (2012) range from 60,000 to 80,000 new units per year. They range from large models designed for factories to the small 1-KW generators. One calculation put aggregate capacity in 2008 at 2500 MW – about equivalent to the national power company's available capacity at the time (The Report Nigeria, 2012). It is evident from the figure above that transmission and distribution loss in electricity have some bearing effect on available energy for consumption, this could be one of the explanations for the persistent supply-demand gap.

Nigeria is believed to have the biggest gap between supply and demand for electricity in the world and the costs occasioned by this poor electricity supply are huge for individuals, businesses and the national economy. According to Central Bank of Nigeria, 60 million Nigerians relied on generators in 2010, and spent $13bn on keeping them fuelled. This amount exclude the larger amount used by industry. Speaking in 2010, the former President Goodluck Jonathan asserted that use of private generator adds 40% to the cost of goods and services. On the national cost, it is estimated that GDP growth could be boosted from 7-8% to 10-11% if power supplies were available (The Report Nigeria, 2012).

The federal government of Nigeria is not unaware of the spate of energy problems in the country. The federal government of Nigeria as a matter of urgency is coming to terms with the trends and characteristics of energy supply and demand. This is manifested in the several attempts it has made in tackling the challenges of the sector with a global perspective. These challenges are in form of technical, economic, institutional and financial; hence the privatization of the power sector. The privatization of the power sector was primarily motivated by a number of factors, such as the need to enhance the business and investor-friendly environment, by providing reliable and constant power supply; to tackle the ever increasing demand for sustainable energy, and to address the need for an efficient distribution, generation and transmission network. Towards this goal, The Nigerian Electrical Power Authority (NEPA) metamorphosed into The Power Holding Company of Nigeria (PHCN) PLC in 2005. Also in 2005, the Nigerian Electricity Regulatory Commission (NERC) was created as regulator for the sector; followed by the incorporation of 18 successor Companies comprising of 6 generation companies (GENCOs), 11 distribution companies (DISCOs) and one transmission company (TCN), and the establishment of a Liquidation Committee to wind down the operations of PHCN in 2011. The privatization process of 2012 and 2013 saw the assets of the state's Power Holding of Nigeria (PHCN) unbundled into the 18 successor companies – the GENCOs; the DISCOs and the TCN ((The Report Nigeria, 2012). With this, the Federal Government successfully relinquished its exclusive hold on the power sector, though it retained the management of the Transmission Company. The above reforms and programs are geared towards secure and stable energy access that will meet the ever increasing energy demand in Nigeria. However, the Nigeria's electricity problem has not been just one of quantity, but also of reliability and efficiency. Thus, drawing from historical time series data on the determinants of electricity supply in Nigeria, the study aims to empirically assess the optimal electricity supply in Nigeria. This is necessary since the question of whether Nigeria's electricity supply is optimal or not has not been investigated to the best of the researchers' knowledge. Again, the paper employed the Partial Adjustment Model (PAM) approach to econometric modeling. Partial Adjustment Model has been used in many areas of applied economics as a description of how expectations are formed. This rest of the paper is structured as follows: following the introduction in section 1 is the literature review in literature review in section 2, section 3 provides the analytical framework and model specification, section 4 dwells on the data analysis and discussion of results and section 5 concludes with recommendations.

2. Review of Related Literature

The relationship between energy and economic growth has been of an increasing concern in recent studies, hence leading to plethora of studies in this area. In generally, most of these studies have concentrated on the demand side of electricity that is, energy consumption and economic growth. For instance, Onakoya, Onakoya and Salami (2013) evaluated the causal nexus between energy consumption and Nigeria's economic growth for the period of 1975 to

2010 in a six variable regression model which includes: Economic Growth (GDP), Total Energy Consumption (TEC), Petroleum (PT), Gas (GS), Electricity (ELECT) and Coal (CO). Secondary time-series data were analyzed using Co-integration and Ordinary Least Square (OLS) techniques. The study shows that in the long run, total energy consumption has a similar movement with economic growth except for coal consumption. The empirical results reveal that petroleum, electricity and the aggregate energy consumption have significant and positive relationship with economic growth in Nigeria. On the question of threshold cointegration and causal relationship, Esso (2010) investigated the long-run and the causal relationship between energy consumption and economic growth for seven Sub-Saharan African countries during the period 1970–2007. Using the Gregory and Hansen testing approach to threshold co-integration, the study indicates that energy consumption is co-integrated with economic growth in Cameroon, Cote d'Ivoire, Ghana, Nigeria and South Africa. The test suggests that economic growth has a significant positive long-run impact on energy consumption in these countries before 1988; and this effect becomes negative after 1988 in Ghana and South Africa. Furthermore, causality tests suggest bi-directional causality between energy consumption and real GDP in Cote d'Ivoire and unidirectional causality running from real GDP to energy usage in the case of Congo and Ghana.
Odhiambo (2009) applied the newly developed autoregressive distributed lag (ARDL) bounds test approach and Granger non-causality test for Tanzania for the 1971-2006 period. The results of the bounds test revealed a stable long-run relationship between energy consumption and economic growth. While, the results of Granger non-causality showed the evidence of unidirectional causality running from energy consumption to economic growth as well as from electricity consumption to economic growth. The results imply that energy conservation policies have damaging repercussions on economic growth for Tanzania. Furthermore, Mehrara (2007) looked at the relationship between the per capita energy consumption and per capita GDP on the basis of panel data for 11 oil exporting countries for the period 1971-2002 and employing the panel cointegration technique and Granger causality test. The results showed a unidirectional causality from economic growth to energy consumption for all the countries. The results indicated that energy conservation policies have no damaging effect on economic growth for this group of countries.

Similarly, other studies, such as: Odularu and Okonkwo (2009) and Dantama, Umar and Abdullahi (2012), have studied the relationship between electricity consumption and economic growth and the possible effect of electricity consumption on economic growth. The evidence from Odularu and Okonkwo (2009) indicates that there exists a positive relationship between energy consumption and economic growth. This finding is also in line with Dantama et al (2012) whose findings among others indicate a long-run relationship between economic growth and energy consumption.

However, on the supply side (electricity generation, distribution and transmission), empirical evidence on the optimal or desired electricity supply in Nigeria is almost non-existent. Most of the studies, Ohwafosa, Obeh and Erakpoweri (2015); Ogagavwodia, Edafe and Onoriode (2014), Ubi et al (2012) et cetera have focused on the impact of electricity supply on economic growth and the determinant of electricity supply in Nigeria.

For instance Ohwafosa, Obeh and Erakpoweri (2015) investigated the impact of electricity Supply on economic growth in Nigeria for the period 1980 – 2010 with per capita income, electricity consumption, export, government expenditure and investment as the variables of study. The study employs an error correction model and results show that there was no long run relationship between per capita income and the explanatory variables. And in the short run while electricity consumption, government expenditure and investment exert positive impact on per capita income, the relationship between the later and export is negative. Finally the ECM observed the usual negative slope with very high speed of adjustment.

Similarly, Ogagavwodia, Edafe and Onoriode (2014) studied the nexus between the Power Supply and National Development from 1980-2012 in Nigeria. Three different single equation models were specified, with GDP as the dependent variable in one of the models while megawatt of electricity generated; population (a proxy for labour force) and capital (a proxy for gross fixed capital formation) were used as the explanatory variables. Using Co-integration and Parsimonious Error Correction Model, the results among others indicate that megawatts of electricity generation which is the variable of interest exerts positive influence on real GDP but negative impact on index of industrial production all of which are statistically insignificant.

On the determinants of electricity supply in Nigeria, Ubi, Effion, Okon and Oduneka (2012) carried out an econometric analysis of the determinants of electricity supply in Nigeria for the period 1970-2009, with electricity supply, electricity price, government funding, annual rainfall, level of technology and power loss as the variables of the study. Using cointegration technique and Parsimonious error correction mechanism, the results show that technology, government funding, and the level of power loss are the statistically significant determinants of electricity supply in Nigeria and that an average of 40% of power is lost in transmission per annum. The study further recommends that, the government should inject more funds into the power sector to complete power projects with state of the art technology in order to enhance electricity supply.

Building on Ubi, Effion, Okon and Oduneka (2012) and drawing from historical time series data in Nigeria, this current study extends the frontier of knowledge on electricity supply-macroeconomy nexus, by assessing the optimal or desired electricity supply in Nigeria using the partial adjustment model technique. The thrust of this study is to empirically evaluate the actual electricity supply in Nigeria vise-a-vise the potential electricity supply.

3. Theoretical Framework and Model Specification

The traditional supply theory is the basic theoretical underpinning of this research. Supply in this context is not necessarily the total stock of a product produced but it is the amount that is actually offered for sale. Thus, supply is most of the time less than the production. It is a common knowledge that producers tend to offer more for sale at a higher price and less at a lower price, all things being equal. The forgoing is reinforced by the classical theory of supply. The above postulation is an ideal situation in a perfectly competitive market.

However, given the nature of electricity product in Nigeria and the fact that it is produced by a monopoly firm enjoying the advantages inherent in a monopolistic market structure, the law of supply as stated above may not necessarily apply. In line with the theory of supply, there are factors that determine the quantity of a product that may be offered for sale at any given price. These factors are price of the commodity, cost of production, state of technology, natural phenomenon like rainfall, government policy, etc. It is apparent from the literature reviewed, that the determinants of electricity supply in Nigeria are not limited to the factors highlighted above. It should be noted that these factors to a greater extent determine the quantity (may be quality also) and regularity of electricity offered for sale by the electricity organization in Nigeria. It is on the basis of these factors that affect electricity supply in Nigeria that we adopt a baseline model specification for this study.

The Model

In line with theoretical framework, we begin the model specification with a static electricity supply (ES) function which depends on electricity price (EP) per megawatt hours, volume of electricity generated or produced (EG), government spending on electricity (GS), technology (TECH) and the quantity of electricity loss (EL):

Thus:

$$ES_t = F\,(EP_t, EG_t, GS_t, TECH_t, EL_t) \qquad (1.1)$$

In stochastic form, the above model can be expressed as:

$$ES_t = \beta_0 + \beta_1 EP_t + \beta_2 EG_t + \beta_3 GS_t + \beta_4 TECH_t + \beta_5 EL_t + \varepsilon t \qquad (1.2)$$

Where:

ES; EP; EG; GS; TECH and EL are as defined earlier, while ε_t is the stochastic disturbance term at time t.

The above model specification is in tandem with the literature and the supply theory reviewed which allows for the identification of the determinants of electricity supply. The model specification also follows that of Ubi et al (2012) and Subair and Oke (2008).

The variables in equation (1.2) are all in natural logs. From the static electricity supply model above, we derive the partial adjustment model (PAM) for Nigeria electricity supply, which is the thrust of this study.

Partial adjustment model

The partial adjustment model comprises two parts, a static part to describe how the desired amount is determined and the dynamic partial adjustment process. We begin the derivation of partial adjustment electricity supply model with the static model which defines the desired or optimal level of electricity supply.

Thus:

$$ES_t{}^* = \beta_0 + \beta_1 EP_t + \beta_2 EG_t + \beta_3 GS_t + \beta_4 TECH_t + \beta_5 EL_t + \varepsilon t \qquad (1.3)$$

Equation (1.3) is the static partial adjustment model which describes how the desired amount is determined.

The coefficients β_j *(for j = 1, 2, 3, 4, 5 and 6)* provide the long – run elasticity.

$ES_t{}^*$ defines the desired or optimal electricity supply in Nigeria. The desired or optimal electricity supply ($ES_t{}^*$) is not directly observed while the observed electricity supply (ES_t) follows partial adjustment mechanism.

Therefore:

$$ES_t - ES_{t-1} = \lambda(ES_t{}^* - ES_{t-1}) \qquad (1.4)$$

Where lambda (λ) is the adjustment parameter

Substituting the optimal level of electricity supply function (Equ 1.3) into the partial adjustment (Equ 1.4), we obtain:

$$ES_t - ES_{t-1} = \lambda(\beta_0 + \beta_1 EP_t + \beta_2 EG_t + \beta_3 GS_t + \beta_4 TECH_t + \beta_5 EL_t + \varepsilon t - ES_{t-1})$$

Multiplying through with λ yields:

$$ES_t - ES_{t-1} = \lambda\beta_0 + \lambda\beta_1 EP_t + \lambda\beta_2 EG_t +$$

$$\lambda\beta_3GS_t + \lambda\beta_4TECH_t + \lambda\beta_5EL_t + \lambda\varepsilon t - \lambda ES_{t-1}$$

$$ES_t = \lambda\beta_0 + \lambda\beta_1EP_t + \lambda\beta_2EG_t + \lambda\beta_3GSt + \lambda\beta_5TECH_t + \lambda\beta_6EL_t + \lambda\varepsilon t - \lambda ES_{t-1} + ES_{t-1}$$

$$ES_t = \lambda\beta_0 + \lambda\beta_1EP_t + \lambda\beta_2EG_t + \lambda\beta_3GS_t + \lambda\beta_4TECH_t + \lambda\beta_5EL_t + (1-\lambda)ES_{t-1} + \lambda\varepsilon t \qquad (1.5)$$

From equation (1.5)

$$ES_t = \prod_0 + \prod_1EP_t + \prod_2EG_t + \prod_3GS_t + \prod_4TECH_t + \prod_5EL_t + \prod_6ES_{t-1} + V_t \qquad (1.6)$$

Equation (1.6) is the partial adjustment model whose coefficients represent the short-run elasticity. The short-run parameters describe the short run effects of the explanatory variables on the dependent variable. On the other hand, the long-run coefficients can be derived from the short-run parameters as follows:

$\beta_0 = \prod_0/\lambda;\ \beta_1 = \prod_1/\lambda;$
$\beta_2 = \prod_2/\lambda;\ \beta_3 = \prod_3/\lambda;$
$\beta_4 = \prod_4/\lambda;\ \beta_5 = \prod_5/\lambda;$
$\prod_6 = 1-\lambda$ (or $\lambda = 1- \prod_6$), and $\lambda\varepsilon t = V_t$ (or $\varepsilon t = V_t/\lambda$).

The adjustment parameter λ measures the speed of adjustment and lies between 0 and 1. The closer it is to 1 the faster the speed of adjustment.
Where: $\lambda = 1- \prod_6$
On a priori, we expect $\prod_1;\ \prod_2;\ \prod_3;\ \prod_4;\ \prod_6 > 0$ while $\prod_5 < 0$.

Estimation Procedure

Prior to the estimation of the partial adjustment model (PAM) of equation (1.6), and the subsequent derivation of the optimal electricity supply, the time series properties of the variables are investigated. The purpose is to determine the order on integration. The unit root test is conducted using the modified Ng-Perron unit root test procedure developed by Ng and Perron (2001). Ng and Peron (2001) propose some modifications to the Phillips (1987) test (MZa), Phillips and Perron (1988) (MZt), Bhargava (1986) (MSB), and the Point Optimal Test by Elliot, Rothenberg and Stock (1996) (MPT). This is done by combining a Modified Information Criterion for the lag length and a Generalised Least Squares method for detrending the data. The choice of this test over the traditional unit root tests (ADF, PP and KPSS) is based on the fact that they are more suitable for small sample and efficient in presence of structural breaks. The Autoregressive Distributed Lag (ARDL) approach (which utilizes the bounds testing approach to cointegration) proposed by Pesaran and Shin (1999) and Pesaran et al. (2001) is used in this study. This technique has a number of features that many researchers feel give it some advantages over the approach suggested by Engel-Granger (1987) and the maximum likelihood based approach proposed by Johansen and Juselius (1990) and Johansen (1991). Firstly, it can be used with a mixture of I(0) and I(1) data, that is, it can be used whether the variables are mutually cointegrated or not. Secondly, it involves just a single-equation set-up, making it simple to implement and interpret. Thirdly, different variables can be assigned different lag-lengths as they enter the model. And, the model can be tested by using the OLS (ordinary least square) once the order of ARDL has been recognized (Pesaran and Shin 1999; Pesaran et al 2001).

In addition, the technique addresses the problem of endogeneity. Pesaran and Shin (1999) posit that modeling with ARDL with the appropriate lags will correct for both serial correlation and endogeneity problem. However, endogeneity is not a serious problem if there is no serial correlation in the estimated ARDL model. All the variables in the ARDL model are assumed to be endogenous and the long and short run parameters are estimates simultaneously.
The ARDL model is derived from equation (1.2) as follows:

$$\Delta ES_t = \theta_0 + \sum_{p=1}^{n} \theta_1 \Delta ES_{t-1} + \sum_{p=1}^{n} \theta_2 \Delta EP_{t-1} + \sum_{p=1}^{n} \theta_3 \Delta EG_{t-1} + \sum_{p=1}^{n} \theta_4 \Delta GS_{t-1} + \sum_{p=1}^{n} \theta_5 \Delta TECH_{t-1} + \sum_{p=1}^{n} \theta_6 \Delta EL_{t-1} + \Phi_1 ES_{t-1} + \Phi_2 EP_{t-1} + \Phi_3 EG_{t-1} + \Phi_4 GS_{t-1} + \Phi_5 TECH_{t-1} + \Phi_6 EL_{t-1} + \varepsilon t \quad (1.7)$$

The model in equation (1.7) above is similar to conventional error model, the difference is that that lagged value of $ES_;$ $EP_;$ $EG_;$ $GS_;$ TECH and EL have replaced the error vector; EC_t.

The short-run effect can be measured by the coefficient of first difference variables (θj for j = 1, 2 ..……. 6) while the long-run effect can be inferred by the estimates of Φ_j (for j = 1, 2 …………..6).
Suppose the null hypothesis of no cointegration is rejected, equation (1.7) provides the long run equilibrium level of electricity supply, and a short run error correction model of the form:

$$\Delta ES_t = \theta_0 + \sum_{p=1}^{n} \theta_1 \Delta ES_{t-1} + \sum_{p=1}^{n} \theta_2 \Delta EP_{t-1} + \sum_{p=1}^{n} \theta_3 \Delta EG_{t-1} + \sum_{p=1}^{n} \theta_4 \Delta GS_{t-1} + \sum_{p=1}^{n} \theta_5 \Delta TECH_{t-1} + \sum_{p=1}^{n} \theta_6 \Delta EL_{t-1} + VECt + \varepsilon_t \quad (1.8)$$

Where v is the coefficient of the error term which measures how the short run disequilibrium in the model adjusts within a period.

Sources and Measurement of Data

This study uses annual time series spanning from 1980 to 2014 for Nigeria. The data set is sourced from Central Bank of Nigeria Annual Bulletin various issues, World Bank Development indicators (WBDI), the Global Economy. The data on Electricity Supply (ES), Electricity Generation (EG) and Electricity (transmission and distribution) Loss (EL) are expressed in megawatt hour. Government Spending (GS) is what is actually spent on the power sector expressed in billion (naira). Electricity Price (EP) is the average electricity tariff by residential, commercial and industrial and electricity use per capita kilowatt hour is use as a proxy for Technological Progress (TECH).

3. Empirical Results and Discussion

Summary Statistics

We begin the empirical analysis by presenting the summary statistics of variables employed in the study. The table below shows the summary statistics of data on Electricity Supply (ES), Electricity Generation (EG), Electricity Loss (EL), Electricity Price (EP), Government Spending on power (GS) and Level Technology (TECH) in Nigeria for the period 1980 – 2014. The result is shown in table 1 in the appendix.

The skewness values for almost all the variables are nearly zero, with four of the variables (EG; EL; EP and GS) having negative values indicating skewness to the left, while the remaining two variables (ES and TECH) have positive value, indicating skewness to the right. The mean to median ratio of each variable is within the unit proximity and the standard deviations are relatively low, indicating small variability.

Unit Root Test

In order to forestall the incidence of spurious regression, the integration properties of the data set used in estimation of equ (1.6) needs to be verified. The study applied the modified Ng-Perron test. The summary of the stationarity tests for the variables are presented in table 2 in the appendix. The result indicates that all the variables under scrutiny except electricity loss (EL) are integrated of order one. This implies that electricity supply, electricity generation, electricity price, government spending and level of technological progress are I(1) process, while electricity loss is I(0) process. This is an ideal situation for ARDL Bound Testing approach to cointegration, since the approach is efficient in handling I(1) and I(0) variables at the same time.

Cointegration Test

Given the results of Ng-Perron unit root tests, we then proceed to test for the existence of long-run relationship among the variables. The ARDL Bound Testing approach proposed by Pesaran and Shin (1999) and Pesaran et al. (2001) is appropriate since there are mixture of I(0) and I(1) variables. We determine the appropriate lag structure for the ARDL model in equ (1.7), we also make sure that the errors in model are serially independent and that the model is dynamically stable before the Bound Testing. Using Schwarz Information Criterion (SIC) and Akaike Information Criterion (AIC) a four-period lag length model is appropriate. The autocorrelation test shows that the error terms are serially independent. Again the inverse roots of each of the associated characteristic equations (see the inverse roots of AR/MA polynomial(s) in the appendix), suggests that the AR (4) model is dynamically stable since these roots are all inside the unit circle. Since the AR (4) model is dynamically stable and the errors are serially independent, we then proceed to perform the bound testing. Given the null hypothesis;

H_0: $\Phi_1 = \Phi_2 = \Phi_3 = \Phi 4 = \Phi_5 = \Phi_6 = 0$, against the alternative that H_0 is not true.

Decision rule:

Case 1: Reject H_0 if the F-value is greater than the upper bound.

Case 2: Accept H_0 if the F-value is less than the lower bound.

Case 3: Inconclusive if the F-value falls between the lower and upper bounds.

The value of our F-statistic is 2.725347 (see the Wald coefficient test in the appendix), we have (k + 1) = 6 variables (ES, EP, EG, GS, TECH and EL)

From the Bounds Tests tables[1] of critical values, we have K = 5. The lower and upper bounds for F-test at 10% significance level are 2.26 and 3.35 respectively. Comparing the F-calculated and the F-critical shows that the F-calculated falls between the lower and upper bounds, this indicates inconclusive. This result may imply partial cointegration among the variables.

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[1] Table CI (iii) on page 300 of Pesaran et al (2001) is the appropriate table, because the intercept in our model haven't been constrained and no linear trend term is included in the ECM.

Estimation of the Partial Adjustment Model

The partial adjustment model is estimated to account for both the shot-run and long-run impact of the determinants of electricity supply on electricity supply, and assess the speed of adjustment of electricity supply to changes in its determinants. The result of the short-run elasticity estimates of the partial adjustment model is shown in the appendix. The result indicates that electricity generation; governments spending on electricity and level of technology have positive impact on electricity supply in the short-run, with electricity generation and level of technology exerting significant effect on electricity supply while the impact of government spending on electricity seems unfelt for the period. On the other hand, electricity price and one-period lag of electricity supply have negative but insignificant impact on electricity supply, electricity loss shows negative and significant effect on electricity supply for the period under study. The F-statistic indicates the impact of the variables on electricity supply is statistically significant. The adjusted R-Square is about 0.99, this implies that about 99% changes in electricity supply is caused by variations in electricity price, electricity generation, government spending on power, level of technology, electricity loss and the lag value of electricity supply. We use the Breusch-Godfrey (BG) test, also known as the Lagrange Multiplier (LM) test to test whether there is any high-order autocorrelation within the model. The result (in table 5 in the appendix) shows that the computed n*R-Square is approximately 2 with, probability value of 0.37. Thus, at the 5% significant level we reject the H_0 that there is the first-order autocorrelation in the autoregressive model. The partial adjustment parameter (λ) which measures the speed of adjustment of electricity supply to changes in its determinants in the short-run is approximately equal to one (1). This implies that observed changes are equal to desired changes in electricity supply in Nigeria for the period, that is, full adjustment. The result also indicates that the short-run coefficients of the drivers of electricity supply in Nigeria are equal to the long-run coefficients (this derivation is shown in the appendix).

The Optimal Electricity Supply in Nigeria

The next task is to derive the optimal or desired electricity supply in Nigeria using the long-run coefficients of the derivers of electricity supply. To achieve this, we pick some periods (between 1980 and 2014); estimate the optimal value by substituting the observe values (of electricity price, electricity generation, government spending on power, level of technology and electricity loss) into the desired electricity supply function (the long-run electricity function) and then compare the value with the actual electricity supply.

The long-run electricity supply is given by equation (1.3) as:

$$ES_t^* = \beta_0 + \beta_1 EP_t + \beta_2 EG_t + \beta_3 GS_t + \beta_4 TECH_t + \beta_5 EL_t + \varepsilon t$$

Illustrations

The table below shows the observed (actual) values of electricity supply (MWH); electricity price (in naira); electricity generation (MWH); electricity loss (MWH); government spending (in billion naira), and the level of technology in Nigeria for some selected periods:

Table 1: actual values of the variables of study for some selected periods (except the errors computed by the authors).

Year	ES	EG	EL	EP	GS	TECH	Errors
1980	5085000	7169000	2084000	0.6	0.37	67.8036485	-
1985	6863000	10221000	3358000	0.6	0.110189	80.12960711	-0.00896

1990	8291000	13463000	5172000	4	0.015	86.71020479	0.001122
1995	9876000	15857000	5981000	4	1.426277	91.08614948	-0.01348
2000	9109000	14727000	5618000	4	31.97	74.13120631	0.0322771
2005	17959000	23539000	5580000	4	93.29	128.659135	0.016138
2010	21624000	26121000	4497000	9.15	194.52	135.3972862	0.050289
2014	25434000	27742000	2308000	16.44	20.6	189.52197	-0.07786

Sources: WDI, PHCN, the global economy, (2015)[2].

Substituting the above values of EG, El, EP, GS, TECH and Errors for the respective period in their appropriate places into:

$$\mathbf{ES_t^* = 1.40 - 0.009EP_t + 0.93EG_t + 0.009GS_t + 0.48TECH_t - 0.158EL_t} + \varepsilon t$$

Yields:

Table 2: optimal, actual, supply shock and percentage of supply shock to optimal electricity supply in Nigeria for some selected periods

Year	ES_t in MW (actual)	ES^*_t MW (optimal)	ES_t - ES_t^* (supply shock)	Supply shock as % of ES_t^*
1980	5,085,000	6,313,356.509	-1,228,356.509	-19.46%
1985	6,863,000	8,939,958.898	-2,076,958.898	-23.23%
1990	8,291,000	11,657,275.59	-3,366,275.59	-28.88%
1995	9,876,000	13,747,666.38	-3,871,666.59	-28.16%
2000	9,109,000	12,757,987.07	-3,648,987.07	-28.61%
2005	17,959,000	20,929,032.6	-2,970,032.6	-14.19%
2010	21,624,000	23,492,603.65	-1,868,603.65	-7.95%
2014	25,434,000	25,340,526.87	93,473.13	0.37%

Source: the Authors' computation, (2015)

From the above illustrations, the actual electricity supply has been less than the optimal level, except in 2014. For instance, in 1980 and 2010, the actual supply lagged behind the optimal value by 1,228,356.509 MW and 1,868,603.65 MW, representing about 19.46% and 7.95% loss in potential electricity supply respectively. However, the actual electricity supply exceeded the desired electricity supply in 2014 by about 93,473.13 MW representing about 0.37%. One of the reasons that can be adduced for this impressive performance in 2014 is the unbundling of the power sector which has enhanced efficiency and reduced inertia in transmission and distribution of electricity. The figure below shows the actual and desired electricity supply in Nigeria for some selected periods from 1980 to 2014.

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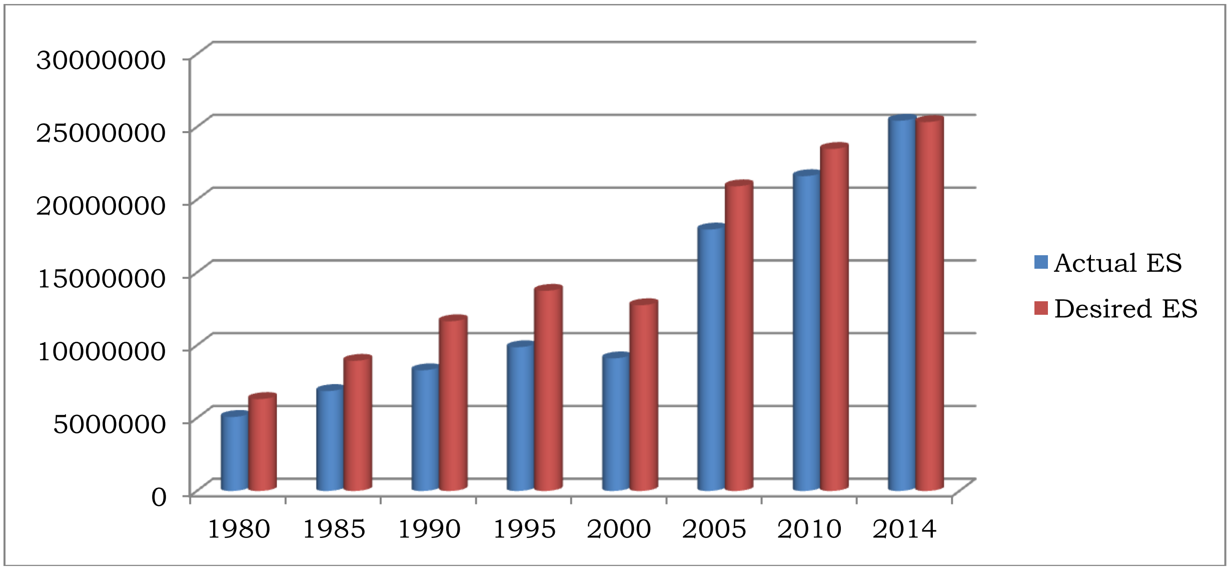
2 Tech and errors computed by the researchers.

Figure 1.2: the actual and desired electricity supply in Nigeria for some selected periods from 1980 to 2014.



Source: the authors' computation, (2015).

4. Conclusion and Policy Recommendations

Inadequate electricity supply has affected the Nigeria economy rather badly. The problem of electricity supply in Nigeria is not just of quantity but also of reliability and efficiency. The study examines the optimal or desired electricity supply in Nigeria from 1980 to 2014 using partial adjustment model of electricity demand that is estimated in a fixed-effects OLS framework. This model formulation allows for the coefficient of elasticity to be expressed in both its short-run and long-run forms. The stationary properties of the series are explored using modified Ng-Perron unit root test. The results reveal that all the variables are I(1) process except electricity loss which is I(0). The ARDL Bound Testing approach to cointegration reveals an inconclusive evidence of long-run relationship among the variable of study. The estimate of the partial adjustment equation reveals that electricity generation, government spending and level of technology are positively related to electricity supply with electricity generation and level of technology being statistically significant. On the other hand, electricity price, electricity loss and lag value of electricity supply exert negative effect on electricity supply, with only electricity loss being statistically significant. The partial adjustment parameter (λ) which measures the speed of adjustment of electricity supply to changes in its determinants in the short-run is approximately equal to one (1). This implies that observed changes are equal to desired changes in electricity supply in Nigeria for the period, that is, full adjustment; the electricity supply function is sensitive to changes in its drivers. The result also indicates that the short-run coefficients of the derivers of electricity supply in Nigeria are equal to the long-run coefficients.

Furthermore, the findings also reveal that actual electricity supply in Nigeria for the period under review has been less than the optimal level, except in 2014. In 1980 and 2010, the actual supply lagged behind the optimal value by 1,228,356.509 MW and 1,868,603.65 MW, representing about 19.46% and 7.95% loss in potential electricity supply respectively. However, the actual electricity supply exceeded the desired electricity supply in 2014 by about 93,473.13 MW representing about 0.37%. One of the reasons that can be adduced for this impressive performance in 2014 is the unbundling of the power sector which has enhanced efficiency and reduced inertia in transmission and distribution of electricity. In line with major findings, the paper, therefore recommends the following:

(1) That government should inject more funds/subventions into the power sector in order to complete the various power projects with state of the art technology; adequate security measure should be put in place to protect electricity generation, transmission and distribution equipments from being vandalized. (2) Efficient supply management measures (rationing) should also be put in place and consumer should be educated on energy conservation methods. (3) The findings also indicate that price is not a significant variable that affects electricity supply in Nigeria; this in part may be due to the fact payment rates for electricity bills are low, government should therefore formulate and implement appropriate pricing policy that can affect profitability and hence, boost electricity supply. (4) Hydro-electric and solar system power sources should be made key power sources if the quest to increase electricity supply by more than fivefold by 2020, from the current level of about 3400 MW to 20,000 MW is to be realized. (5) We also recommend that Nigerian Government should go beyond the unbundling of the energy sector and fully liberalize the market and make it competitive.

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Appendix

Table 1: Summary Statistics of the Variables used.

Variable	Mean	Median	Std Dev.	Skewness	Obs.
LES	16.22	16.06	0.50	0.17	35
LEG	16.57	16.56	0.39	-0.26	35
LEL	15.21	15.21	0.49	-0.51	35
LEP	1.08	1.39	1.03	-0.51	35
LGS	0.76	0.35	3.36	-0.12	35
LTECH	4.58	4.51	0.30	0.36	35

Table 2: Summary of Ng and Perron 2001 Modified Unit Root Test

Variable	MZa	MZt	MSB	MPT	Order of integration
ΔLES	**-14.8691**	**-2.71656**	**0.18270**	**6.18713**	**I(1) @ 10%**
1%	-23.8691	-3.4200	0.14300	4.03000	
5%	-17.3000	-2.91000	0.16800	5.48000	
10%	-14.2000***	-2.62000***	0.18500***	6.67000***	
ΔLEG	**-15.9017**	**-2.80977**	**0.17670**	**1.57773**	**I(1) @ 1%**
1%	-13.8000*	-2. 58000*	0.17400*	1.78000*	
5%	- 8.10000	-1.98000	0.23300	3.17000	
10%	-5.70000	-1.62000	0.27500	4.45000	
LEL	**-7.49061**	**-1.911719**	**0.25595**	**3.33644**	**I(0) @ 10%**
1%	-13.8000	-2. 58000	0.17400	1.78000	
5%	- 8.10000	-1.98000	0.23300	3.17000	
10%	-5.70000***	-1.62000***	0.27500***	4.45000***	
ΔLEP	**-16.4767**	**2. 86499**	**0.17388**	**1.50640**	**I(1) @ 1%**
1%	-13.8000*	-2. 58000*	0.17400*	1.78000*	
5%	- 8.10000	-1.98000	0.23300	3.17000	
10%	-5.70000	-1.62000	0.27500	4.45000	
ΔLGS	**-16.0992**	**-2.83717**	**0.17623**	**1.52186**	**I(1) @ 1%**
1%	-13.8000*	-2. 58000*	0.17400*	1.78000*	
5%	- 8.10000	-1.98000	0.23300	3.17000	
10%	-5.70000	-1.62000	0.27500	4.45000	
ΔTECH	**-15.0305**	**-2.74034**	**0.18232**	**6.06881**	**I(1) @ 10%**
1%	-23.8691	-3.4200	0.14300	4.03000	
5%	-17.3000	-2.91000	0.16800	5.48000	
10%	-14.2000***	-2.62000***	0.18500***	6.67000***	

Note: * and *** indicate that the series is stationary at 1% and 10% levels of significance respectively.

Table 3: The inverse roots of AR/MA Polynomial(s) test for model stability

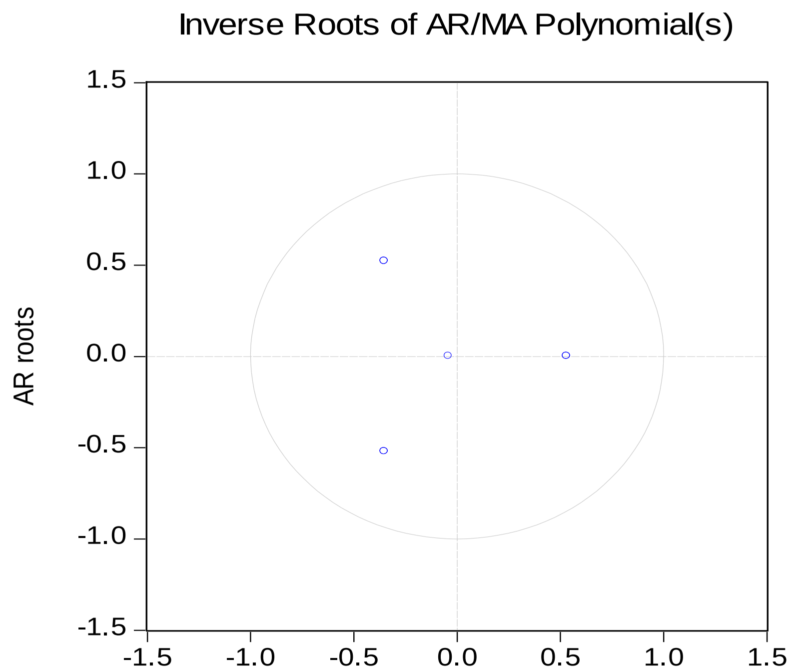

Table 4: Wald coefficient restriction test

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	2.725347	(6, 14)	0.0573
Chi-square	16.35208	6	0.0120

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(11)	2.844759	1.588201
C(12)	0.093611	0.093078
C(13)	-2.760859	1.441310
C(14)	-0.003448	0.039388
C(15)	-1.820933	1.291562
C(16)	0.351295	0.271050

Restrictions are linear in coefficients.

5: Summary of short-run and long-run elasticity of the partial adjustment model (equations 1.6 and 1.3 respectively)

VARIABLE	**SHORT-RUN ELASTICITY**	**LONG-RUN ELASTICITY**
Intercept	$\prod_0$ = 1.398750 (0.3710)	$\beta_0 = \prod_0/\lambda$ = 1.398750
EP	$\prod_1$ = -0.009216 (0.5937)	$\beta_1 = \prod_1/\lambda$ = -0.009216
EG	$\prod_2$ = 0.926579 (0.0000)**	$\beta_2 = \prod_2/\lambda$ = 0.926579
GS	$\prod_3$ = 0.008747 (0.1178)	$\beta_3 = \prod_3/\lambda$ = 0.008747
TECH	$\prod_4$ = 0.476045 (0.0002)**	$\beta_4 = \prod_4/\lambda$ = 0.476045
EL	$\prod_5$ = -0.158024 (0.0001)**	$\beta_5 = \prod_5/\lambda$ = -0.158024
ES(-1)	$\prod_6$ = - 0.019448 (0.6934)	
	R^{-2} = 0.99, F-stat = 1201 (000)** n* R-Square = 1.966 Prob. (X^2) = 0.3741	
	$\lambda = 1- \prod_6$ = 1.0194	

Note ** indicates statistically significance at 5% significance level. Probability values are in bracket.