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The Dynamics of Demand and Supply of Electricity in Nigeria

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Abstract

This paper presents an empirical analysis of the demand and supply of electricity in Nigeria. The analysis was performed using annual times series data for the period 1970 to 2012. For this purpose, we estimated the long–run demand and supply equations for electricity using the reduced form regression method (RFRM) and the Vector error correction method (VECM) approach. Our analysis revealed that the theoretical modeling requirements rather than the simplified reduced form regression in the simultaneous equation system to satisfy the statistical requirements determine the choice of the statistical model. The results from the estimated model in terms of individual parameters in the system revealed that both price and income are demand elastic. As such, increasing electricity price in Nigeria would lead to a reduction in revenue by Power Holding Company of Nigeria (PHCN). The study also show that PHCN is currently experiencing diseconomies of scale as a result of inefficiency, inability to innovate as well as the necessary knowledge needed to expand output so as to reduce average cost. Similarly, the paper posits that the current reform in the electricity sector would only lead to increase in average unit cost and hence the price of electricity. We therefore recommend that for the Nigerian electricity sector to be viable as well as meet the supply and demand needs of both the private, commercial and industrial sector of the economy, the government at all levels, policy and decision makers must take stringent measures to curtail the problem of inefficiency, lack of manpower, be able to innovate so as to reduce wastage to its lowest web. This will not only bolster the growth of the Nigerian economy but will also be a source of revenue for the government for its infrastructural development needs.

Keywords: Electricity demand and supply, Annual data, Simultaneous equation method and Vector error correction method (VECM)

INTRODUCTION

Electricity power or energy is the bedrock for economic growth and industrialization of any country. The process of setting up of an electricity generating system is costly and time consuming but once it is in place, it is expected to experience a decreasing average costs as the output expands. Also, the system is expected to innovate and make use of advances in knowledge and technology. These learning and experiences so far gained on the production process should enable the system expand and produce better output than previously as a result of the existence of the economy of scale as well as the learning effects. Nigeria has never enjoyed an adequate supply of electricity in its history as unmet demand and constant losses have been the characteristics of electricity generation. Prior to Nigeria’s independence, electricity was known and used only by some government headquarters and the first electricity plant was built in 1950 and government corporated a department to form the Electricity Corporation of Nigeria (ECN) with the sole responsibility for generation, distribution, transmission and sale of electricity to all consumers in the country. After independence in 1960, the Niger Dam Authority (NDA) was promulgated in 1962 by an Act of parliament with similar functions as the ECN and it operated the electricity industry from 1962 – 1972. To make the industry efficient, the two agencies (ECN and NDA) were merged and transformed to the Nigerian Electric Power Authority (NEPA) in 1973 as a limited liability company. It acquired Ijora, Delta, Afam and Kainji power stations with a total installed capacity of 532.6MW serving more than two million Nigerians. But the supply is still far short of demand, which is estimated to range from 700MW to 900MW. Given the electricity tariff at £0.15 per kWh is extremely costly for the Nigerian standard which has an average monthly earnings of £60 (CBN, 1973). However, energy was increased to 2948MW in the mid 80s to late 90s before it jumped sharply to 5958MW in 2000 with electricity tariff at ₦12.50 per kWh is extremely costly for the Nigerian standard which has an average monthly earnings of ₦18,000 (CBN, 2011, NEPA, 2001). This led to the Electricity Power Sector Reform (EPSR) in 2005 with the view of making private sector the major engine of growth as well as reintegrate Nigeria into the global economy as a platform to attract foreign direct investment (FDI) in an open transparent manner. This metamorphosed into the repeal of the NEPA Act and its restructuring. This gave birth to Nigerian Electricity Regulatory Commission (NERC), Rural Electricity Agency (REA) and the National Electricity Management Company (NEMNCO) to manage the residual assets and liability of the defunct NEPA. This gave birth to a company called Power Holding Company of Nigeria (PHCN) all in 2006. These efforts led to an increase in power generation of 7042MW between 2001 and 2008 yet it was far below the net demand of 10000MW and the performance is unsatisfactory as it continues to loss 50% of its production as unmetered consumption. Thus, the company has no option but to learn and innovate to improve the performance. Does the cost structure of PHCN tell of economies of scale, learning and innovation? This paper will attempt to answer this question as well as attempt to analyze the structure of demand for electricity in Nigeria. Nigerians increasingly buy electrical appliances to consume the power (energy) produced by PHCN or by chemical batteries, generators and solar panels while the industrial consumers often set up stand–by generators to complement the PHCN supply. It is not economical for every individual to operate her own electricity generating system. If the consumers in Nigeria increasingly demand or plan to demand high consumption to energy, it will be learned that they are willing to pay for the energy; and PHCN provided that its cost structure exhibits economies of scale, should in the position to increase output to make up the demand that is increasingly offered by both households and the industrial consumers. The remaining part of this paper is divided into three. Section II is literature review, Section III data, Section IV econometric modeling and results while Section V focuses on conclusions.

LITERATURE REVIEW

There exist various studies on the tenets and determinants of electricity demand. These studies focus on the demand for electricity as a function of its own price, income of the individual among numerous variables deemed to be relevant. Some of these other variables are climatic condition Hondroyannis (2010), household size to plasma display panel television Yoo et al (2007), Joskow (2008). Other studies reveals that electricity was found to be a basic necessity of living, Louw, et al (2008), Isola (2007), Narayan, Smyth and Prasad (2007), Narayan and Smyth (2005), Makoju (2002), Bhagavan (1999). Electricity demand was also found to be unitary elastic in response to changes in income (Joutz et al, 2004). In a similar vein, studies by Yoo et al (2007), Joutz et al (2004), Hondroyannis (2010) and Joskow (2008) found electricity demand to be price inelastic. This is true for the electricity market because it has no close substitute in the short–run while a study by Hondroyannis (2010) revealed that electricity demand in Greece is a luxury. The own price of electricity was found to be insignificant, Ziramba (2008); Isiola (2007 and 2005); Ugbongu (1985) and Taiwo (1982). This can be attributed to price discrepancies, distortions as well as measurement error often associated in the electricity market.

Studies by Isola (2007), Joutz et al (2004) and Hondroyannis (2010) found the demand for electricity to be inelastic in both the short– and long– run while Narayan et al (2007) opined it to elastic only in the long run. This means that in the long run, consumers are able to adjust their consumption of electricity by switching to other sources of energy. All these studies assumed that the supply of electricity is constant. This view is correct in a cross sectional data but questionable in time series data. Hondroyannis (2010), observed an identifiable and stable electricity demand while Sargsyan et al (2006) suggest a shifting electricity demand. Similarly, studies by Kahouli–Brahmi (2009) and Kamershen and Porter, (2004) focuses on the supply side of the electricity market while assuming electricity demand to be constant. Therefore, analyzing electricity demand or supply differently without reference to the interdependency with electricity supply or demand would lead to biased results and conclusions. This paper therefore attempts to fill this gap by analyzing the demand and supply of electricity simultaneously. This paper adopted the augmented model of Fischer and Kaysen (1962) to estimate both the learning and scale effects which reduces the omitted variable bias that is often associated when estimating the learning curves. The simultaneous equation approach was also employed by Kamershen and Porter, (2004) but their model excluded the learning effect. Furthermore, the paper pioneers this study in the context of Nigeria, where no such study has been conducted. As such it provides evidence base which is of high value to policy makers in Nigeria.

Source of data

Annual times series date spanning a period of 42 year (1970 – 2012) would be collected and analyzed. The data would be sourced from IMF country statistical appendices of Nigeria, World Development Report, CBN Annual Reports and Statistical Bulletin as well as from the National Bureau of Statistics. PHCN has three main sales prices (residential, business and commercial prices). These prices are averaged to find the mean price ($\overline{P}$). There are there variables to be used in this paper. The variables are consumer price index, which is used to find real per capita income gross domestic product (GDP), real per capita GDP is used as a proxy for the income variable in the electricity demand function, the total actual consumption of electricity (i.e. households, firms and government).

Econometric Modeling – demand and supply and result

A. The demand model

The demand for electricity is a derived one because it is demanded for the services of electrical machines as well as other electrical appliances. Electricity demand decreases or increases when the use of these machines and appliances decreases/increases or as a result of new purchases of these machines and appliances, retirement or retooling. The paper adopted the augmented Fischer and Kaysen (1962) model to evaluate household electricity demand. The household demand for electricity is as a result of their demand for the services of the different machines and appliances. The stocks of these goods are often measured in terms of the total kilowatts per hour that could be consumed, if the appliances are used at their maximal rate. It is therefore pertinent to know the number of kilowatts per hour that could be consumed by each appliance and then sum them up over the different electrical appliances. Hence, the sum of kilowatts per hour consumption of the different appliances used by a household say i gives us the stock of appliances used by household i. let X_{it} be the total number of appliances used by household i at time t while the demand for electricity will depend on the rates of used of the appliances. This can algebraically represented thus: $Q_{it} = f(X_{1t}, X_{2t})$ ……………………………(1) where Q_{it} = Total energy consumption of household i at time t; X_{1t} = The rate of use of the appliances by household i; X_{2t} =The total stocks of the electrical appliances.

But X_{1t} is assumed to depend on per capita income (PCY_{it}) and the prevailing price of electricity (P_{it}). Therefore, equation (1) can be rewritten as $Q_{it} = f(P_{it}^{\alpha} PCY_{it}^{\beta} X_{it})$ …………………………………… ..(2)

Where α and β are stands for price and income elasticity for demand for electricity respectively. We can infer from here that the demand for electricity depends on the prevailing price of electricity, the household income and the stocks of electrical appliances. Equation (2) is a multiplicative demand function that shows $P_{it}^{\alpha} PCY_{it}^{\beta}$ is an index that when multiplied by the total stocks X_{it} which determines the level of actual electricity consumed by household i. Hence equation (2) can be rewritten in an econometric log linear form thus: $InQ_{it} = \alpha InP_t + \beta InPCY_t + InX_{it}$………………………….. (3).

However, the stock of appliances would grow over time hence we assumed a constant growth rate of K per year. This can be mathematically written as $\frac{X_t}{X_{t-1}} = ex(K)$ or $InX_t - InX_{t-1} = K$…………….. ..(4)

Using equation (4), we lagged equation (3) by one period thus $InQ_{t-1} = \alpha InP_{t-1} + \beta InPCY_{t-1} + InX_{t-1}$ …..(5). Subtract equation (5) from (3) will result into:

$$InQ_{it} - InQ_{t-1} = InX_{it} - InX_{t-1} + \alpha(InP_t - InP_{t-1}) + \beta(InPCY_t - InPCY_{t-1}) \text{ ……………………………} \quad (6)$$

But from equation (4), $InX_t - InX_{t-1} = K$. Substitute this into (6), we get,

$$\Delta InQ_{it} = K + \Delta InP_t + \Delta InPCY_t + u_t \text{ ……………………………..……………………………..…} \quad (7)$$

Equation (7) is the first difference operator while assuming that $\mathbf{u_t}$ is independently and identically distributed with mean zero and variance of one. Then, we can estimate equation (7) using ordinary least square (OLS) method.

However, the price of electricity poses a measurement challenge in Nigeria, as it is often offered as price blocks to consumers, as such no one price exists. Also, the blocks are fairly constant over time causing the price variable to be a constant. This is can be confused with the intercept term in the equation. This study is based on times series approach whose observation span over a long period. Therefore, price changes are frequently observed. We adopted the average tariff ($\overline{P}$) for all the sectors that make up the economy to replace P in equation (7). The first difference operator always gives or leads to the short–run multipliers of the house household demand for electricity while upholding our earlier assumption on the price setting relation. Then, the actual electricity consumption Q depends on the unit average cost ($\overline{P}$) and the per capita income (PCY). Therefore, in the long–run, Q can be written thus: $\text{In}\, Q_t^* = \beta_0 + \beta_1 \overline{P_t} + \beta_2 PCY_t + \mu_t$ ……………………………………… ….. (8)

By adopting the Koyck approach of estimating a long –run equation model and assuming that the adjustment process towards the equilibrium follows this form $\text{In}Q_{it} - \text{In}Q_{t-1} = \beta(\text{In}PCY_t^* - \text{In}PCY_{t-1}^*)$ ………………… (9)

Where $\boldsymbol{\beta}$ is the adjusted coefficient. Hence, both the short– and long– run multipliers can be estimated and derived thus:

$$\left.\begin{aligned} \text{In}Q_t^* &= \alpha\beta_0 + (1-\alpha)\text{In}Q_{t-1} + \alpha\beta_1\text{In}\overline{P}_t + \alpha\beta_2 PCY_t + \mu_t \\ &\text{or} \\ \text{In}Q_t^* &= \lambda_0 + \lambda_1\text{In}Q_{t-1} + \lambda_2\text{In}\overline{P}_t + \lambda_3 PCY_t + \mu_t \end{aligned}\right\} \quad \ldots\ldots (10)$$

Where $\lambda_0 = \alpha\beta_0$; $\lambda_1 = (1-\alpha)$; $\lambda_2 = \alpha\beta_1$; $\lambda_3 = \alpha\beta_2$. While $\boldsymbol{\beta}$**'s** are the long–run multipliers and $\boldsymbol{\alpha\beta}$**'s** are the short–run multipliers. $\boldsymbol{\lambda}$**'s** are derived after estimating equation (10)

B. The supply model or the learning and cost function

The learning curve expresses the relationship between the unit average costs and the cumulative output. Therefore, if a company innovates and its workforce accumulates experiences then the output will expand more than before at the same give cost. The cumulative output that captures advances in knowledge, technology and experiences would have negative relationship with the unit average cost. This linear relationship is specified by Berndt (1991) thus:

$\text{In}C_{it} = \text{In}\beta C_0 + \text{In}\pi_{it} + \mu_{it}$ ………………… ….(11)

From equation (11), $\boldsymbol{\mu_{it}}$ is assumed to be independently and identically distributed with a mean of zero and a variance of one. While $\mathbf{C_{it}}$ is the average unit cost of PHCN, $\mathbf{C_0}$ is the initial average unit cost, $\boldsymbol{\pi_{it}}$ is the cumulative output up to but excluding time **t** and **t** is the time series observations. If we assume that the production of electricity follows a Cobb–Douglas production function and adopting the augmented Berndt model, we can derive the unit average cost function which account for information on advances in technologies, economies of scale as well as returns to scale. If we assume that:

a. Power Holding Company of Nigeria (PHCN) employs only two inputs – labour **(L)** which include all human resources that goes into producing as well as facilitating the production of electricity and capital **(K)** include all non–human resources that goes into the production of electricity output.
b. **Z** is the electricity output that is produced using the technology T^π for combining L and K. π is the technology elasticity of the electricity output.
c. The production function of electricity in Nigeria is, $\mathbf{Z_{it} = T^\pi L^\alpha K^\beta}$ ………………………… ….(12)
d. where $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are the input elasticity of output and $\boldsymbol{\alpha + \beta = \lambda}$ which indicates the returns to scale. But if PHCN is to have economies of scale then $\boldsymbol{\lambda}$ must be greater than one.
e. The input prices are $\mathbf{P_1}$ and $\mathbf{P_2}$ for **L** and **K** respectively. Hence, the budget constraint for PHCN with C as its total budget would be thus: $\mathbf{C_{it} = P_1L_{it} + P_2K_{it}}$ …..………………… ….(13)

The problem of PHCN is to maximize equation (12) subject to equation (13).

$Z_{it} = T^\pi L^\alpha K^\beta$ ……………………………… …. (12)

$C_{it} = P_1L_{it} + P_2K_{it}$ ………………………… … (13)

From equation (13) $C_{it} – P_1L_{it} – P_2K_{it} = 0$ ……………… ……….. (14)

Multiply equation (14) by λ

$\lambda(P_1L_{it} + P_2K_{it} – C_{it}) = 0$ …………………… . (15)

Combine equation (12) and (15)

$Z = T^{\pi}L^{\alpha}K^{\beta} + \lambda(P_1L_{it} + P_2K_{it} – C_{it}) = 0$ ……………………… …………(16)

By suppressing time subscripts for simplicity, the problem is reduced to maximizing a Langragian function of thus:

$Z_L = \alpha T^{\pi}L^{\alpha-1}K^{\beta} – \lambda P_1 = 0 \Longrightarrow \alpha T^{\pi}L^{\alpha-1}K^{\beta} = \lambda P_1$………………………… ……. (17)

$Z_K = \beta T^{\pi}L^{\alpha}K^{\beta-1} – \lambda P_2 = 0 \Longrightarrow \beta T^{\pi}L^{\alpha}K^{\beta-1} = \lambda P_2$………. …... (18)

$Z_{\lambda} = C – P_1L – P_2K = 0$ …………………………… ……... (19)

Divide equation (17) by equation (18) gives you,

$$\frac{\alpha L}{\beta K} = \frac{P_1}{P_2} \Rightarrow \alpha LP_2 = \beta KP_1 \Rightarrow L = \frac{\beta KP_1}{\alpha P_2} \quad \ldots\ldots\ldots\ldots \quad (20)$$

Substitute equation (20) into equation (12) gives us,

$$Z = T^{\pi}L^{\alpha}K^{\beta} \Rightarrow Z = T^{\pi}\left(\frac{\beta KP_1}{\alpha P_2}\right)^{\alpha}K^{\beta} \Rightarrow Z = \frac{T^{\pi}\beta^{\alpha}K^{\alpha}P_1^{\alpha}K^{\beta}}{\alpha^{\alpha}P_2^{\alpha}} \Rightarrow Z\alpha^{\alpha}P_2^{\alpha} = T^{\pi}\beta^{\alpha}K^{\alpha}P_1^{\alpha}K^{\beta}$$

$$K^r = \frac{Z\alpha^{\alpha}P_2^{\alpha}}{T^{\pi}\beta^{\alpha}P_1^{\alpha}} \text{ But let } \alpha + \beta = r \therefore K^r = \frac{Z\alpha^{\alpha}P_2^{\alpha}}{T^{\pi}\beta^{\alpha}P_1^{\alpha}} \text{ or } = Z\alpha^{\alpha}T^{-\pi}\beta^{-\alpha}P_2^{\alpha}P_1^{-\alpha} \ldots\ldots\ldots. \quad (21)$$

Substituting equation (21) into equation (20) gives the value of **L**:

$$L = \beta P_1\alpha^{-1}P_2^{-1}(Z\alpha^{\alpha}T^{-\pi}\beta^{-\alpha}P_2^{\alpha}P_1^{-\alpha}) \Rightarrow L = P_2^{\alpha/r}P_1^{-\alpha/r}T^{-\pi/r}Z^{1/r}\alpha^{\alpha/r}\beta^{-\alpha/r} \ldots\ldots\ldots.. (22)$$

Substituting equations (21) and (22) into equation (19) generate the cost function thus:

$$C = BP_2^{\alpha/r}P_1^{-\alpha/r}T^{-\pi/r}Z^{1/r} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

Equation (23) can be rewritten in a linear natural logarithms by adding the stochastic term μ, gives the cost function in econometric form thus:

$\text{In } C_t = \beta_0 + \beta_1 InT_t + \beta_2 InZ_t + \beta_3 InP_{1t} + \beta_4 InP_{2t} + \mu_t$ ……………… ….(24)

Where $\beta_0 = \text{InB}$; $\beta_1 = \frac{\alpha}{r}$; $\beta_2 = \frac{1}{r}$; $\beta_3 = \frac{\alpha L}{r}$; $\beta_4 = \frac{\alpha K}{r}$

InT is the constant term and **Z** is the technology term. The time variable can be used to proxy for technology. Also, from the learning curve, **Z** is the cumulative output variable and as such **Q** can replace **Z** in equation (24). However, the appearance of input prices as explanatory variable can complicate the estimation results. Output is an explanatory variable in the supply function and it is traditionally defined to be a function of output. But Berndt (1991), assumes that some price index is a function of the input prices, hence, in this paper we assume the consumer price index as a function of the input prices thus:

InCPI $= \frac{\alpha L}{r} InP_{1t} + \frac{\alpha K}{r} InP_{2t}$ so that real cost of electricity $C_t^r = \frac{C_t}{CPI_t} \Rightarrow C_t^r = InC_t - InCPI_t$. By subtracting In C_t and $InCPI_t$ we derive the real cost thus:

$$InC_t^r = InB + \alpha/rInT + 1/r\,InZ_t + \alpha L/r\,InP_{1t} + \alpha K/rInP_{2t} + \mu_t - \alpha L/rInP_{1t} - \alpha L/rInP_{2t} \ldots (25)$$

From equation (25), the price variable will cancel out and the variable T that represents advances in knowledge and technology can be replaced with the variable Q from the learning curve, where Q represents the cumulative output and captures the learning experiences as well as advances in technology. T and Q are different measures of the same variable. If we assume that T = W; then equation (25) can be rewritten as:

$$InC_t^r = InB + \alpha/\mathrm{r}InW + 1/r\,InZ_t + \mu_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (26)$$

From equation (26), we derive the real average cost (RAC) of the electricity as total cost (TC) divided by output (Z).

$$RAC_t = \frac{C_t^r}{Q_t} \text{ or } InB + \alpha/rInW + (1-r)/r\,InZ_t + \mu_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad \ldots (27)$$

Equation (27) can be used to estimated thus $InB + \lambda_1 InW_t + \lambda_2 InZ_t + \mu_t$ ……… …………...(28)

Since PHCN is a regulated monopolist company, its price would be proportional to its average cost thus:

$\overline{P_t} = \sigma C_t$ where $\overline{P_t}$ is the average price for all the consumers at time t, σ is the constant or proportionality. Taking the constant of natural logarithms of this relation and solving for average cost, we have: $InC_t = In\overline{P_t} - In\sigma$ ………………………………… …….(29)

Substitute equation (29) into (28), we arrive at: $In\overline{P_t} = InB + \lambda_1 InW_t + \lambda_2 InZ_t + \mu_t \ldots$ ……(30)

where T = InB + Inσ; $\lambda_1 = \frac{\alpha}{r}$; $\lambda_2 = \frac{1-r}{r}$

If returns to scale are increasing, **r** will be greater than one. If returns to scale are decreasing, **r** will be less than one and if it the returns to scale are constant, **r** would be one as such, would not be significantly different from zero. Therefore, after estimating equation (30), the returns to scale and economies of scale can be computed thus:

Returns to scale, $r = \frac{1}{\lambda_2 + 1}$ while the economies of scale, $ES = \frac{-\lambda}{\lambda_2 + 1}$.

The demand equation [equation (10)] and the supply equation [equation (30)] form a 2 by 2 system of equations.

Quantity demanded of electricity = f(Price, income, last period quantity demanded)

$$InQ_t^* = \lambda_0 + \lambda_1 InQ_{t-1} + \lambda_2 In\overline{P}_t + \lambda_3 PCY_t + \mu_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . \;.(10)$$

Price of electricity = f(Cumulative output, current output)

$$In\overline{P_t} = InB + \lambda_1 InW_t + \lambda_2 InZ_t + \mu_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad \ldots \ldots (30)$$

Spanos (1990) opined that the identification and simultaneity problems associated with the supply and demand model arises because available data refers to quantities transacted and the corresponding prices over time. However, in equation (30), Z_t is not the quantity transacted, the quantity transacted is Q which is the actually produced and purchased. Whereas Z is the total output produced that includes the quantity purchased and the unmetered output including own consumption. Therefore, to treat the identification and simultaneity problems in our model, equation (30)'s current output, Z is replaced by Q. the actual transacted quantity plus unmetered production [UM], which modifies the equation thus:

$$\mathrm{In}\overline{\mathrm{P}_t} = \mathrm{InB} + \lambda_1 \mathrm{InW}_t + \lambda_2 \mathrm{In}(\mathrm{Q}_t + \mathrm{UM}_t) + \mu_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (31)$$

The reduced forms that results after solving equations (10) and (31) together for p and q values are estimated and examined for the identification of the structural parameters, then we employ the Vector Error Correction (VEC) method to complement the reduced form method (Spanos, 1990)

C. Results

The results of the reduced form estimates for quantity demanded as well as the price variable that are derived as a result of the simultaneous solution of equation (10) and (31) which do not fit the underlying data on electricity demand and supply in Nigeria are presented in Table 1 and 2 respectively. The coefficients of the parameters are mostly insignificant though there are no serial correlation or heteroskedasticity problems to render the t–ratios unreliable. The structural slope coefficients of the parameters are over–identified while the structural constants parameters cannot be identified. Three explanations can be adduced for the results in Table 1 and 2. First, the explanatory variables are found to be highly correlated. The correlation coefficients exceed eighty–nine point six percent between the two variables and no variable can be dropped as explained in sections' IV (a) and (b). This is because the stimulus variables have been theoretically introduced as such they are vital for the model coupled with the issue of reliable data that are that prevalent LDCs do not allows us to expand the scope. Secondly, the presence of lagged quantity demanded variable as exogenous variable came as a result of Fischer et al (1962) electricity modeling which gave credence to the fact that not all regressor variables in the reduced forms are exogenous that violate the assumptions of reduced form regressions. Thirdly, results in tables 2 and 3 used the level variable in its estimation but in Table 1, the variables of the model were mostly I(0), therefore the estimated relationship in the reduced form regression are spurious.

Furthermore, explanations 2 and 3 cannot be avoided when estimating the demand and supply functions with the learning effects, but they have rendered the reduced form estimate unreliable. This means that a system simultaneous equation can be easily reduced to some regression equations and then estimated and solved for the structural parameters when indeed some predictors are theoretically irrelevant for some independent variables. This is the position of this paper. For example, the cumulative production is not important for the electricity demand. Similarly, the income variable supposes not to appear in the estimation of the supply function of electricity but this fact is ignored by the reduced form regressions. However, to correct this, we introduced the vector autoregression (VAR) to form the model by incorporating the restrictions that in the demand function, cumulative output and unmetered output are not necessary while in the supply function, the income variable do not appear as well as further restricting that the coefficient estimate of the quantity variable and that of the unmetered output are equal in the supply equation which emanates as a result of replacing the total production with **Z** with the actual quantity purchased (**Q**) plus the unmetered output (**H**). The model is likely to produce two cointegrating equations. The first cointegrating equation would represent the demand function while the other, the supply function of electricity in Nigeria respectively. Furthermore, two restrictions would be imposed to identify these equations thus:

i. In the demand function cointegrating equation, the cointegrating vectors are normalized by the cointegrating coefficients of the quantity purchased while per capita income (**PCY**) would be treated as predictor variable. Similarly, cumulative electricity output and the unmetered output are treated as irrelevant variables.
ii. In the supply function cointegrating equation, the cointegrating vectors are normalized by the cointegrating coefficients of the average price while the coefficient of the quantity purchased (**Q**) is equated to the coefficient of the unmetered output for fit equation (31). And per capita income (**PCY**) would be treated as unnecessary.

These two restrictions produce two cointegrating equations. The first equation has no trend and intercept while the other has intercept but no trend. The restrictions of the model with no trend and no intercept are rejected at one percent level of significance as shown in Table 4. The restrictions of the model with intercept but no trend cannot be rejected at five percent level of significance as indicated in Table 3. The results in Table 3 reveal that the electricity demand is price inelastic and income elastic. This means that a 1% increase in electricity price would lead to an average of 32.45% decline in the quantity of electricity demanded. Similarly, a 1% increase in income would lead to an average of 39.57% rise in the quantity of electricity demanded. Therefore, in Nigeria electricity demand is price elastic as such the revenue would fall if the average price increases. Conversely, it is income elastic since it is a luxury for the average Nigerian. The total electricity demand would be expensive and profit generating as long as the percentage price increase is less than 1.3 times of per capita income growth rate. With a projected per capita income growth rate of 8% in 2013, PHCN an increase its average electricity by10.7% and this would lead to a positive increase in its revenue. PHCN should however be able to satisfy the expansion in its electricity demand through innovation, economies of scale to reduce its average unit cost and expansion of its supply.

The income growth of is a major constraint on profitable price increase if the projected maximum price increase of 10.7% cannot land PHCN in profit, if it continues to lose more than 30% of its production to inefficiency and corruption as captured in the supply function. The estimated coefficient of return to scale is 0.097 which also gives a factor of economies of scale of minus 1.097. This suggest that PHCN's operation exhibits decreasing returns to scale and diseconomies of scale which implies that under the period of study, on the average, PHCN has not innovated as well learnt from past experiences. As such it has not been able to accumulate any useful knowledge to enable it to expand output nationwide. The little that has been expanded has been at a corresponding increasing average cost as revealed by the coefficient of the cumulative output. Therefore, charging increasing high electricity price to recover the inefficient average cost cannot be sustained as percentage price increase exceeding 1.3 times of per capita income growth rate. This will result in a shrink in electricity demand. This is captured in the estimated demand equation, which shows that PHCN's operation is in the price elastic region where price increase can only lead to a reduction in its revenue. Hence, it can only increase its revenue by reducing or lowering electricity prices. Therefore, the ongoing restructuring of PHCN operations in its entirety by government should be pursued with all vigour to its logical conclusion while modernizing its systems to minimize the unmetered production that is currently put at 57% of its total production cost.

Conclusion

The paper has revealed that the system of simultaneous equations cannot be simply solved into reduced form regressions for estimation purposes. The theoretical modeling should also define the statistical paradigms or properties. It also shows that the vector error correction method (VECM) which incorporates the theoretical restrictions is better suitable and fits the data than the reduced form regression. The demand for electricity in Nigeria is elastic hence PHCN cannot increase it revenue by further increasing the electricity price but only by reducing the price can result in increased revenue for the company. This is only a constraint on the demand side. However, the major constraint of the electricity industries lies in the production side that is found to exhibiting diseconomies of scale as a result of inefficiency in electricity production in the country as such any major expansion can only be achieved via the increase in average unit cost and its price. The findings of the paper indicates that for electricity demand not to shrink, PHCN should not charge an average unit price that is higher than 1.3 times of the citizens per capita income. We therefore recommend that government and policy makers should be committed to its logical conclusion, the current effort aimed at reorganizing or restructuring of PHCN to make it more efficient by reversing its current inefficiency or wastage that stands at 57%.

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Table 1: Reduced form regression for electricity demand

Dependent Variable: LOG(Q)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-8.519156	3.380667	-2.515496	0.0803
LOG(Q(-1))	1.099196	0.046356	23.71185	0.0000
LOG(UM)	0.022584	0.043050	0.524599	0.1682
EP	0.260560	0.503011	0.518001	0.6912
LOG(PCY)	0.393137	0.904798	0.434503	0.4623

R-squared	0.895675	Mean dependent var	71.50291
Adjusted R-squared	0.857943	S.D. dependent var	0.155124
Log likelihood	63.63735	F-statistic	72.25065
Durbin-Watson stat	1.859483	Prob.(F-statistic)	0.000000
White Heteroskedasticity Test:	17.27295	Probability	0.512982
Ramsey RESET Test:	13.62631	Probability	0.752317
BG Serial Correlation LM Test:	23.19269	Probability	0.325598

Table 2: Reduced form regression for electricity supply

Dependent Variable: LOG(P)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-11.03693	12.24026	-0.901691	0.3724
LOG(Q(-1))	0.788911	0.064562	12.21934	0.0000
LOG(UM)	-0.001808	0.001097	-1.648485	0.1067
EP	0.012083	0.011984	1.008282	0.3191
LOG(PCY)	1.011603	0.144161	7.017178	0.0000

R-squared	0.874612	Mean dependent var	71.50291
Adjusted R-squared	0.801997	S.D. dependent var	0.155124
Log likelihood	7.317765	F-statistic	72.25065
Durbin-Watson stat	1.443661	Prob.(F-statistic)	0.000000
White Heteroskedasticity Test:	11.54395	Probability	0.723199
Ramsey RESET Test:	0.965433	Probability	0.541231
BG Serial Correlation LM Test:	16.76456	Probability	0.346501

Table 3: Vector Error Correction Estimates for demand and supply of electricity in Nigeria

Cointegration Restrictions:
B(1,1)=1,B(1,2)=1, B(2,2)=1, B(1,5)=0, B(2,1)=B(2,5), B(1, 4)=0,
B(2,3)=0, A(5,1)=0, A(4,1)=0, A(3,1)=0
Convergence achieved after 97 iterations.
Restrictions identify all cointegrating vectors
LR test for binding restrictions (rank = 2):

Chi-square(5)	24.195385
Probability	0.022739

Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eqn:	CointEqn1	CointEqn2
C	991.6779	-19.25447
	(2.66613)	(4.13206)
	[371.9543]	[-4.65978]
LOG(Q(-1))	1.000000	8.63761
		(4.55626)
		[1.89577]
LOG(P(-1))	7.327841	1.000000
	(3.18614)	
	[2.29991]	
LOG(UM(-1))	0.000000	8.63761
		(4.55626)
		[1.89577]
LOG(PCY(-1))	-17.25468	0.000000
	(3.79956)	
	[-4.54123]	
LOG(EP(-1))	0.000000	-2 1.37865
		(1.22927)
		[-17.39123]

Error Correction:	D(LOG(Q))	D(LOG(P))	D(LOG(UM))	D(LOG(PCY))	D(LOG(EP))
CointEq1	0.062467	-0.062467	29.64389	0.039163	1.505150
	(0.00945)	(0.00945)	(4.40190)	(0.10214)	(0.09766)
	[6.60851]	[-6.60851]	[6.73433]	[0.38343]	[15.4117]
CointEq2	-0.451124	-0.034214	-21.91154	1.350423	-1.138055
	(0.06227)	(0.09233)	(17.0474)	(0.23873)	(0.23276)
	[-7.24461]	[-0.37057]	[-1.28533]	[5.65675]	[- 4.88945]

Demand equation $\log(\mathrm{InQ}_t^*) = 991.68 + 7.33 \log(\overline{P_t}) - 17.25 \log(\mathrm{PCY}_t) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$

Cost equation $\log(\overline{P_t}) = 991.68 + 8.64 \log EP - 21.38 \log(\mathrm{PCY}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (31)$

Table 4: Vector Error Correction Estimates with no trend and intercept for the demand and supply of electricity in Nigeria

Cointegration Restrictions:
B(1,1)=1,B(1,2)=1, B(2,2)=1, B(1,4)=0, B(2,1)=B(2,5), B(1, 5)=0, B(2,3)=0, A(5,1)=0, A(4,1)=0, A(3,1)=0
Convergence achieved after 97 iterations.
Restrictions identify all cointegrating vectors

Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eqn:	CointEqn1	CointEqn2
C	1.538886	0.283150
	(0.51814)	(0.19397)
	[2.97005]	[1.45977]
LOG(Q(-1))	1.000000	0.063094
		(0.16452)
		[0.38351]
LOG(P(-1))	0.111413	1.000000
	(0.20534)	
	[0.54258]	
LOG(UM(-1))	0.000000	0.181400
		(0.30914)
		[0.58678]
LOG(PCY(-1))	- 0.308200	0.000000
	(0.19020)	
	[-1.62044]	
LOG(EP(-1))	0.000000	-0.530160
		(0.20915)
		[-2.53481]

Error Correction:	D(LOG(Q))	D(LOG(P))	D(LOG(UM))	D(LOG(PCY))	D(LOG(EP))
CointEq1	0.102224	- 0.018438	0.094753	0.004625	0.092938
	(0.07490)	(0.06747)	(0.11070)	(0.25111)	(0.09400)
	[1.36488]	[-0.27329]	[0.85594]	[0.01842]	[0.98867]
CointEq2	-0.063047	-0.037356	-0.398526	0.088927	-0.025521
	(0.05285)	(0.04760)	(0.07811)	(0.17718)	(0.06633)
	[-1.19305]	[-0.78474]	[-5.10211]	[0.50191]	[-0.38477]