Journal of Sustainable Society
Vol. 2, No. 1, 2013, 1-11
DOI: 10.11634/216825851302163

The Dynamic Analysis of Electricity Supply and Economic Development: Lessons from Nigeria

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This paper explores the relationship between electricity supply and economic development in Nigeria using annual time series data. The paper emphasized the need for the correct specification of the model on the basis of which estimation would be valid. It carries out stationarity, cointegration tests and estimation of the model using ordinary least squares in the context of error correction mechanism (ECM). The results showed that Per Capita GDP, lagged electricity supply, technology and Capital are the significant variables that influence Economic development in Nigeria. One strong outcome of the study is that despite the poor state of electricity supply, it influences economic development in Nigerian but its impact is relatively very low. It is recommended that efforts should be geared towards the improvement of technology and that the various power projects should be completed with state of the art technology as this will ultimately reduce power loss and boost electricity supply vis-à-vis economic development.

Keywords: Nigeria, electricity, economic development, model, specification, industrialization

Introduction

The use of energy is a close indicator of industrial activity and a significant index of standard of living. In the developing countries of the world, no activity is more basic to the fuller utilization of their resources than the development of the energy industries. In most of tropical Africa, industrialization post-dates the age of steam as a source of energy. Electricity, rather than the steam engine drives the developing industries of modern Africa. The Federal Republic of Nigeria, with the largest population in Africa and an energy resource base by African standards, both rich and varied, demonstrates many of the problems and potentialities of electricity production in the developing countries of the tropical world (Simpson, 1969).

Nigeria has an abundant supply of energy sources. It is endowed with thermal, hydro, solar, and oil resources, and yet it is described as an energy-poor country because the sector is relatively under-developed. The statistics available show that only about one third of Nigeria or approximately 40 per cent of the population has access to electricity. The distribution of electricity shows great disparities between rural and urban, and between residential and industrial areas in the urban centres (Ali-Akpajiak & Pyke, 2003). The very poor quality of electricity supply in recent years has been a major constraint on the performance of the economy. As power supply through the Power Holding Company of Nigeria (formerly, National Electric Power Authority) has proved very unreliable. It has become imperative for most industrial or commercial establishments or even individual consumers to acquire diesel standby generating plants at exorbitant costs. Besides, the hazards of diesel fumes to the environment, the situation has contributed significantly to increase in production costs in a highly depressed economy.

Estimates of some of the measurable economic costs of electricity failures have been made by Ukpong (1973; 1976), the World Bank (1993) and Uchendu (1993). The figures are staggering and the economic and financial losses to the economy are highly substantial. Ukpong estimated overall industry loss at N840 000.00 in 1973 and N1,378,000.00 in 1976. He noted that cement and concrete industries suffered most from power failures, followed by food, metal products, textiles and printing industries. In its study, the World Bank estimated the adaptive costs of electricity failure on the Nigerian economy at US $390 million. Of this amount, consumer back-up capacity accounted for $250 million, operating and maintenance cost of diesel auto generators was $90 million, fuel and lubrication was $50 million and the estimate for PHCN (formerly NEPA) lost revenue due to unserved consumer energy amounted to $40 million. Uchendu's estimates of measurable costs associated with electricity failures put the figure at

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N5,662.56 million for the period between 1991 and 1993. Uchendu (1993), Ukpong (1976) and World Bank (1993) referred to in this paragraph concluded that the industrial sector suffered most of the losses. Clearly, electric power shortage is a critical national economic problem, the solution to which must precede meaningful industrialization of the economy. Thus, the quest to rapidly and firmly put the Nigerian economy on the course of economic development is technically, a function of adequate supply and distribution of energy particularly, electricity (Ayodele, 1999).

In this regard, adequate supply and distribution of electricity constitute a central development issue which cannot be over-emphasized. Apart from serving as the pillar of wealth creation in Nigeria, it is also the nucleus of operations and subsequently the engine of growth for all sectors of the economy (Ayodele, 2001). In recognition of the consolidating linkage between the energy sector and the other sectors of the economy, electricity development and utilization therefore have pervasive impacts on a range of socio-economic activities and consequently on the economic progressiveness and wellbeing of citizens of the country. It is in the light of this facts that Okonkwo (2002) stated that there is a correlation between electricity supply, industrialization, and human comfort.

In the 1970s, output growth averaged more than 12 per cent per annum. The performance of the manufacturing sector fell by an average rate of about 1.5 per cent per annum from 1980 to 1984. Average annual growth in manufacturing output fell from 13.8 per cent in the period 1985-1989 to -0.99 per cent and -0.15 per cent for the periods 1990-1994 and 1995-1998 respectively. By 2001, due to stable macroeconomic policies, the sub-sector showed a positive growth of 3.0 per cent and later reduced to 2.8 per cent in 2002. For instance, industrial production in 1986 slowed down considerably than the preceding year 1985. This was due to the sharp reduction in output in both the manufacturing and mining sub-sectors. Furthermore, industrial output continued to be subjected to electric power supply interruptions in spite of the commissioning of a new power station during the year 2006. It is apparently clear from the various indices that measure the performance of the industrial sector in Nigeria that the average capacity utilization for the manufacturing industry in 1975 was 76.6 per cent. In the 1980s, the average capacity utilization fell from 70.1 per cent in 1980 to 43.8 per cent in 1989. The capacity utilization of the manufacturing industry further dwindled in the 1990s and ranged between 29.3 per cent and 42.0 per cent while 36.1 per cent was recorded in 2 000. On the whole, industrial capacity utilization remained low in the industrial sector (Afangideh and Obiora, 2004). This was largely attributed to deficiencies in infrastructural supply in which electricity supply had been the worst over the years.

Also, out of installed capacity of 6-7 gigawatts (GW), only about half can be counted on at any given day. The average electricity generation per capita over a ten-year period of 1985 – 1994 was only 0.12 MWh/capita compared to 0.66 and 8.20 MWh/capita for developing countries (LDCs) and OECD countries respectively (United Nations, 1996, Ndebbio, 2006). Estimated per –capita consumption of electricity in Nigeria is around 16.1kwh which is very poor compared to even Libya with 20.2 kwh. With this situation, South Africa with the consumption of 200.4 kwh per capita cannot be compared to Nigeria in terms of industrialization and overall economic development measured by Gross National Product (GNP) per capita. Indeed, the consumption of electricity in developing African countries going by the three countries is very low relative to the consumption in developed/industrialized countries. For instance, the United States tops the list with 12,399 kwh per capita, followed by Japan (5 594.8), Germany (4 731.8), Italy (7 709.0) (Ndebbio, 2006). Transmission and distribution network is not sufficient to meet growing demand; the system suffers from high level technical and especially non-technical losses (Iledare, 2006).

Considerable efforts have been made to establish the relationship between energy consumption and economic growth. Very few studies have been carried out to investigate the relationship between the energy sub-sector (electricity supply) and economic development in Nigeria. Even the studies in this energy sub-sector and growth tend to be descriptive (Ayodele, 2001; Adegbulugbe and Akinbami, 2002), while others focus on electricity consumption (Ukpong, 1976; Subair and Oke, 2008) rather than supply (which is the bane of economic growth). One of the studies (Udah, 2010) that focused on electricity supply suffered from model mis-specification. The present study hopes to fill the gap by correctly specifying the model and assessing the relationship between electricity supply and economic development in Nigeria. This is important especially in the present circumstance of electricity paradox – shortage in supply in the midst of abundant electricity resource base – which the nation has been facing for some time now. This study is limited to the public power company in Nigeria, Power Holding Company of Nigeria (PHCN). It covers the period from 1970-2009 (a range of thirty nine years). The available time series data within these periods are used to assess the relationship between/among the variables and the

sample range is more than the conventional sample size of thirty. It is believed that this period should be long enough for reliable analysis. More significantly, as it captures different era in the Nigerian economy. Also, it may provide a long term view of the forces that give rise to the poor state of electricity supply in Nigeria.

Literature Review

Electricity, economic development and its issues in Nigeria

The Nigerian economy is the second largest in sub-Saharan Africa, after South Africa in size. Richly endowed with abundant physical and human resources, the economy has the potentials to rank among the richest, most resilient and diversified economies in the developing world. However, after almost four decades of political independence and the execution of economic development plans mainly financed by export proceeds and concessional external borrowing, Nigeria remains one of the poorest countries in the world in terms of per capita income. Until the current decade, economic growth posed significant challenges to the Nigerian economy, especially during the 1980-2000 periods. Key domestic constraints to economic growth and development that have been identified by scholars include but not limited to decaying infrastructure, epileptic power supply, weak fiscal and monetary policy coordination, fiscal dominance, pervasive rent-seeking behavior by private and public agents, including corruption, weak institutions and inordinate dependence on the oil sector for government revenue/expenditure. There are however many issues involved when looking at economic development issues in Nigeria, one of which is power/electricity supply as earlier mentioned and it is the focus of this paper.

The relationship between electricity supply and economic development has been an issue of debate. Odumosu as cited by Subair and Oke (2008) states that for a long time now most role players in the power industry have agreed that the best way to rapid development is through adequate provision of electricity. However, across the African continent, there are differences in levels of power provided such that classification on the basis of sufficiency is complex. Hence, the continent can be categorized into four on the basis of population and land mass. There are small countries with sufficient power such as Lesotho, big countries with sufficient power such as Ethiopia and South Africa, small countries with insufficient power such as Benin Republic and big countries with insufficient power such as Nigeria.

It is therefore necessary for Africa and Nigeria in particular to generate and supply adequate power for development to take place. Infrastructure interacts with the economy through multiple and complex processes. It represents an intermediate input to production, and thus changes in infrastructure quality and quantity affect the profitability of production, and invariably the levels of income, output and employment. Moreover, infrastructure services raise the productivity of other factors of production (Kessides, 1993).

In a study undertaken by Odell (1965) while investigating the role of electricity in a rapidly developing economy like Columbia, he observed that electricity was very important for industrialization which leads to economic growth and development. According to Odell (1965), what is critically important for development is the capacity to consume energy produced and not the capacity to produce it. That is, supply to meet required demand and not supply surplus or excess demand.

A 1991 survey of small enterprises in Ghana cited power outages and other infrastructure problems among the top four problems of operations. With this response strongest among “micro” and small firms. Electricity outage was ranked by very small firms among their top four constraints to expansion (Steel and Webster, 1991). Thus, the issue of electricity supply, its adequacy and reliability is very important for the overall performance of the business sector and the economy and deserves policy attention.

Iwayemi (1998, 2008) opined that there is a strong feedback relationship between the energy sector and the national economy. According to Iwayemi (1998, 2008), energy supply and consumption have enormous impact on social and economic development and the living standard as well as the overall quality of life of the population. On the other hand, the economic structure and the changes in that structure as well as the prevailing macro-economic conditions are key determinants of energy demand and supply. Rapid economic growth and steadily rising income and higher living standards combined with the long term declining trend in energy prices to produce rapidly rising global energy demand/supply.

In the same vein, Oke (2006), demonstrated clearly, the need to improve various infrastructure particularly electricity which is the primary energy required for production. According to Oke (2006), the un-competitiveness of goods in Nigeria is largely due to the fact that apart from other facets of the economy which affect the industrial environment

(manufacturing), electricity has been a largely contributing factor especially the running cost of private generators, rather than diminishing is increasing in leaps and bounds.

Archibong (1997), in his view, stated that the SAP beneficial impact on non-oil sector was short lived partly because of existing structure of the Nigerian economy with its numerous bottlenecks, rigidities and infrastructural (electricity) shortages which tend to undermine the effectiveness of fiscal and other incentives designed to stimulate the growth and diversification of the sector.

Also, Ndebbio (2006) emphasized that an important index that measures whether or not a country is developed is electricity production, supply and consumption. Usually, according to Ndebbio (2006), it is believed by industrial economist that the level of electricity production, supply/consumption determines whether or not a country is developed or industrialized. Thus, we can say that a country's electricity consumption per-capita in kilowatt hours (kwh) is proportional to the state of industrialization of that country. Hence Nigeria performance in electricity consumption (16.1kwh) is very poor compared to some sub-Saharan African countries. He concluded that African countries (Nigeria) have to work extra hard in all fronts to generate and consume more electricity.

Ekpo (2008), as cited by Atser (2008), observed that the most critical aspect of infrastructure to investment is power (electricity) supply which unfortunately had been on the low side in Nigeria. According to Ekpo (2008), statistics from state owned electricity utility firm (PHCN) showed that electricity supply is about 3 400 megawatts in a country of 140million people. He went further to conclude that fixing power (electricity) will spur economic growth and make our industries more competitive.

In a paper on "evaluating investments on basic infrastructure in Nigeria" Aigbokan (1999), wrote that public infrastructure does three things: i) it provides services that are part of the consumption bundle of residents; ii) large scale expenditures for public works increase aggregate demand and provide short-run stimulus to the economy; and iii) it serves as an input into private sector production, thus augmenting output and productivity.

He went further to state that the provision of economic infrastructure can expand the productive capacity of the economy. By increasing the quantity and quality of such infrastructure, the transformation curve or the production possibility frontier or curve would shift with the expansion of the economic infrastructural base, thereby accelerating the rate of growth and enhancing the pace of socio-economic development. And improvements in maintenance would enhance the quality of existing infrastructure and give rise to a "vent for surplus".

More so, Sambo (2008) equally stressed the view that adequate and reliable electricity supply is a major input for achieving socioeconomic development. He further stressed that inadequate supply restricts socioeconomic activities to basic human needs, limits growth and adversely affects quality of life. Nevertheless, the need to establish the relationships between the supply/use of energy (electricity, crude oil etc) and economic growth or output has occupied a central place in most studies while some studies aptly demonstrate that development of energy resources can lead to economic growth through multiplier effect and by providing the infrastructure to facilitate economic development. Others like Yu and Hwang (1984) found no evidence of causality between growth and energy consumption.

Ukpong (1976) in a pioneering work on electricity consumption in Nigeria using a simple regression analysis established that there is a high positive relationships between electricity consumption and economic development on one hand and between electricity consumption and industrialization on the other hand in Nigeria. In other words, electricity consumption is an important infrastructure in accelerating the growth of industries and by extension the economy. Though, he didn't indicate whether the relationship among the variables is bidirectional. He eventually noted that the estimated level of electricity supply was very much short of potential demand.

In his study, Adenikinju (2005), applied both the survey technique and the revealed preference approach to estimate the cost of inadequate electricity supply in Nigeria. One strong outcome of the study is that the poor state of electricity supply in Nigeria has imposed significant cost on the business sector of the Nigerian economy. A situation where firms spend as much as 20% to 30% of initial investment on the acquisition of facilities to enhance electricity supply reliability has a significant negative impact on the cost competitiveness of the manufacturing sector.

Alayande and Ekone (2001), using the multivariate approach (in Nigeria) in which real GDP was modeled as functions of real energy consumption, real energy price, real money supply, real government expenditure and real exchange rate and also modeled real energy consumption as functions of real GDP, real energy price, real money supply, real government expenditure and real exchange rate. That is a GDP-energy consumption model and energy consumption-GDP model was formed and specified by vector autoregressive

models in order to determine the direction of causality between energy consumption and real GDP. The findings of the study showed a unidirectional causality from growth to energy consumption and found no evidence of causality for the other way round. The implication of these findings is that energy consumption has no information on the fluctuation of growth in the Nigeria economy.

Endogenous growth theory (EGT)

This theory attempts to expand the list of basic sources of growth beyond labour, capital, and technological efficiency to include such factors as human capital, knowledge capital or Research and Development (R&D) capital. Endogenous growth theory derives its relevance because of the obvious limitations of the neoclassical model. The motivation for the endogenous growth model stems from the failure of the neoclassical theories to explain the sources of long-run economic growth. The neoclassical theory does not explain the intrinsic characteristics of economies that cause them to grow over extended period of time. The neoclassical theory focuses on the dynamic process through which capital-labour ratios approach long-run equilibrium.

In the absence of external technological change, which is not clearly explained in the neoclassical model, all economies will converge to zero growth. According to neoclassical theory, the low capital-labour ratios of developing countries promise exceptionally high rates of return on investment. Based on this premise, it was expected that the free-market reforms imposed on highly indebted countries by the World Bank and the International Monetary fund (IMF) should have prompted higher investment, rising productivity and improved standards of living. Yet even after the prescribed liberalization of trade and domestic markets, many less developed countries experienced little or no growth and failed to attract new foreign investment or to halt the flight of domestic capital. The anomalous development behaviour of developing-world capital flows (from poor to rich nations) helped provide the impetus for the development of the concept of endogenous growth theory. The new growth theory represents a key component of the emerging development theory. The new growth theory provides a theoretical framework for analyzing endogenous growth, persistent gross national product growth that is determined by the system governing the production process rather than by forces outside that system. In contrast to traditional neoclassical theory, these models hold gross national product growth to be a natural consequence of long-run equilibrium. The principal motivations of the new growth theory are to explain both growth rate differentials across countries and a greater proportion of the growth observed. In particular, endogenous growth theorist seek to explain the factors that determine the rate of growth of gross domestic product that is left unexplained and exogenously determined in the Solow neoclassical growth equation.

Models of endogenous growth bear some structural resemblance to their neoclassical counterparts, but they differ considerably in their underlying assumptions and the conclusion drawn. The most significant theoretical differences stem from discarding the neoclassical assumption of diminishing marginal returns to capital investments, permitting increasing returns to scale in aggregate production and frequently focusing on the role of externalities in determining the rate of return on capital investments. By assuming that public and private investments in human capital generate external economies and productivity improvements that offset the natural tendency for diminishing returns, endogenous growth theory seeks to explain the existence of increasing returns to scale and the divergent long-term growth patterns among countries. And whereas technology still plays an important role in these models, it is no longer necessary to explain long-term growth.

A useful way to contrast the new endogenous growth theory with traditional neoclassical theory is to recognize that many endogenous growth theories can be expressed by the simple equation $Y = Af(K, L)$ as in the Harrod-Domar model. In this formulation, A is intended to represent any factor that affects technology and K again includes both physical and human capital. There are no diminishing returns to capital in this formula, so the possibility exists that investments in physical and human capital can generate external economies and productivity improvements that exceed private gains by an amount sufficient to offset diminishing returns. The net result is sustained long-term growth – an outcome prohibited by traditional neoclassical growth theory. Thus even though the new growth theory re-emphasizes the importance of savings and human capital investments for achieving rapid growth, it also leads to several implications for growth that are in direct conflict with traditional theory. First, there is no force leading to the equilibration of growth rate across closed economies; national growth rates remain constant and differ across countries depending on national savings rates and technology levels. Furthermore, there is no tendency for per capita income levels in capital-poor countries to catch up with those in rich countries with similar savings and population growth rates. A serious consequence of these facts is that a temporary or prolonged recession

in one country can lead to permanent increase gap between itself and wealthier countries. Perhaps, the most interesting aspect of endogenous growth models is that they help explain anomalous international flows of capital that exacerbate wealth disparities between developed and developing countries. The potentially high rates of return on investment offered by developing economies with low capital-labour ratios are greatly eroded by lower levels of complementary investments in human capital, infrastructure, research and development (R&D). In turn, poor countries benefit less from the broader social gains associated with each of these alternative forms of capital expenditure. Because individuals receive no personal gain from the positive externalities created by their own investments, the free market leads to the accumulation of less than the optimal level of complementary capital.

Where complementary investments produce social as well as private benefits, governments may improve the efficiency of resources allocation. They can do this by providing public goods (infrastructure) or encouraging private investments in knowledge-intensive industries where human capital can be accumulated and subsequent increasing returns to scale generated. Unlike the Solow model, endogenous growth theory models explain technological change as an endogenous outcome of public and private investments in human capital and knowledge intensive industries. Thus in contrast to the neoclassical counter revolution theories, models of endogenous growth suggest an active role for public policy in promoting economic development through direct and indirect investments in human capital formation and the encouragement of foreign private investments in knowledge intensive industries such as computer software and infrastructure (Romer, 1986, 1990; Stern, 1991).

The deadweight loss theory

This exists as the consumer/producer surplus is lost. This is more or less due to restriction imposed on output by external factors. Let us consider an industry with the standard shapes of the demand and supply curves. The supply of output by the firm is based on the production function that combines capital, labour, infrastructural services (e.g. electricity) and other inputs. The impact of poor and unreliable supply of infrastructural services would be an increase in the production cost of the firm either through the higher cost incurred in the substitution of private for public supply of those services or through output losses from shutdown by those who cannot effectively find substitutes because they cannot afford to bear the additional cost burden. The effect of this situation is to shift the supply curve to the left (as shown in the diagram below) implying that the producer is only willing to supply each previous level of output at higher price. The higher market price of the product reduces both the consumers and producers surplus. Generally, the inadequate and poor quality supply of infrastructure, such as electric power etc have a major impediment to industrial production and overall economic growth. Some dimension of the loss to the economy can be captured in terms of the deadweight loss (the reduction of consumers and producers surplus) (Iwayemi, 1991). The size of the deadweight loss can be measured by the area ABCR in Figure 1 .

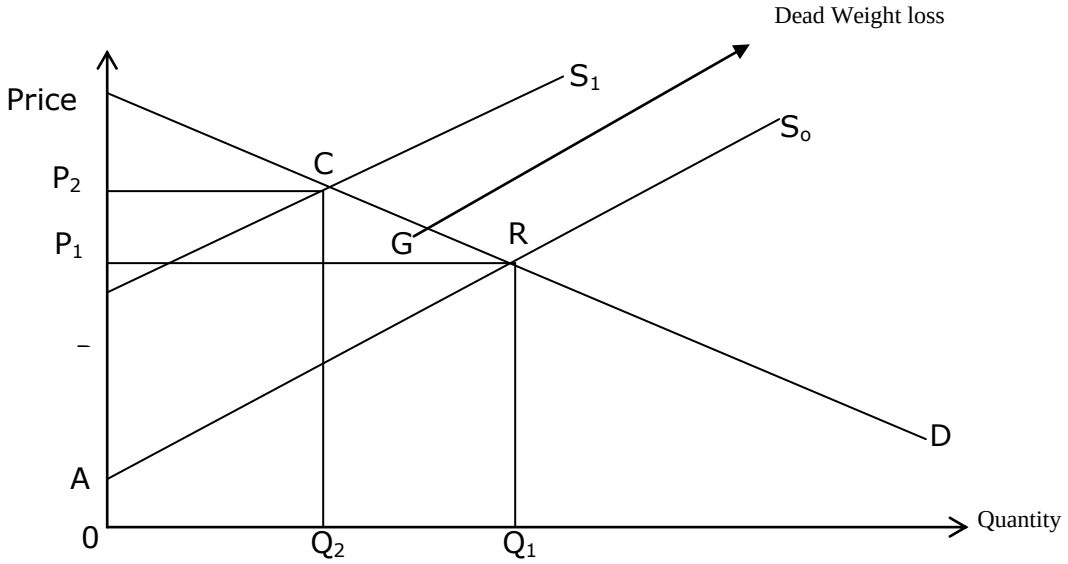

Figure 1: The welfare loss from inefficient supply of infrastructure. .

Improvements in the quality and volume of infrastructural services that have significant economy of scale like electricity would shift the supply curve of producers in the economy outwards and to the right. This would encourage increased production activities, a lower cost structure in the industrial sector and a more competitive industrial environment to meet the tough challenges of the international market place. It is quite an expensive affair for those enterprises that meet their infrastructural requirements through self provision; for after a few years these equipment, which really should be standby but are under continuous use, often need more expensive replacements. They all add up to increase unnecessarily the price paid by the consumer (Iwayemi, 1991).

Data and Methodology

Relevant annual data were collected from National Bureau of statistics and CBN statistical bulletin from 1970 to 2009. Descriptive and analytical techniques were employed. The analysis of the time series data was done using statistical techniques like multiple regression modeling and model estimation based on contemporary econometric estimation methods of ordinary least squares. Stationarity and co-integration test was carried out. The model was estimated in the context of error correction mechanism (ECM).

Stationarity test assures non-spurious result; co-integration captures equilibrium long-run relationships between (co-integrating) variables, and error correction mechanism is a means of reconciling the short-run behavior of an economic variable with its long-run behavior (Gujarati & Sangeetha, 2007).

Model Specification

The regression model is anchored on the endogenous growth theory articulated in theoretical issues. The variables were selected as appropriate. The literature reviewed also uncovered some of the determinants of economic growth. The general endogenous production function is:

$Y = Af(K, L)$ ----------(1)

For simplicity, it is assumed that each industry/economy will use the same level of capital and labour.

Where:

Y = Output (industrial output or gross domestic product)

A = Total factor productivity or efficiency parameter

K = Capital stock

L = Labour

For the purpose of this study, it is assumed that the impact of electricity supply on output (either industrial output or gross domestic product) operates through total factor productivity (A). Since this research work intends to investigate the impact of electricity supply on economic development in Nigeria by correctly specifying the model, it is assumed therefore that total factor productivity (A) is a function of electricity supply (ES) and technology (TECH). Thus,

$A = f(ES, TECH)$ - - (2)

Combining equations 3.1 and 3.2 and substituting for A. We have

$Y = f(ES, TECH, K, L)$ - -- (3a)

Dividing equation 3a by "L" in order to specify economic development equation, given that we are using PCGDP as a proxy for measuring economic development and "L" is part of PCGDP, we have:

$Y/L = PCGDP = f(ES, TECH, K, L)$ - 3b)

"L" cancels out, therefore,

$Y = PCGDP = f(ES, TECH, K)$ - (4)

Where:

ES= Electricity Supply in kilowatt. It should be noted that the quantum of electricity generated does not in reality reflect the actual electricity supplied. It is the quantity of electricity consumed which at best connotes what PHCN could supply that would serve as the measure of electricity supply (ES) (Ayodele, 2001).

TECH = Technology (time variable, one year is one data point).

L =Labour force (labour force in the economy)

K =capital stock (Measured by gross fixed capital formation)

PCGDP = Per capita gross domestic product (a proxy for measuring economic development). Though there are other measures of economic development which includes life expectancy at birth, literacy rate, infant mortality, water supply, housing and increasing flow of goods and services to mention but a few. The Per capita gross domestic product (PCGDP) is used for this study as it is the only proxy for which long trend or time series data are easily accessible in Nigeria.

In order to make the regression functions to be in an estimation form, the functions are reformulated in a log form to include the stochastic error term.

$\ln PCGDP = b_o + b_1 \ln ES + b_2 \ln TECH + b_3 \ln K + U_1$ -- (5)

b_1 to $b_3 > 0$. ln = log of the variables.

U_1 = Stochastic error term. b_o to b_3 represent the various parameters to be estimated measuring the impact of the explanatory variables.

Equation 5 is the correct model to be estimated. Udah, (2010) wrongly specified and estimated a model without cancelling out labour (L) given that it is part of PCGDP and therefore, is not supposed to be one of the independent variables.

Empirical Results

The first step involved in the estimation of a linear relationship is the comprehensive pre-testing procedure to investigate the characteristics of the time series variables. The pre-testing procedure and the regression results are analyzed below.

Using the augmented Dickey-Fuller tests, the results as presented in Table 1 has shown that only technology (TECH) is stationary at the level while other series (variables) are stationary at first difference. That is, the result indicates that the variable, TECH is integrated of order zero – 1(0) while other variables – ES, K, and PCGDP are integrated of order one – 1(1).Therefore, a co-integration test was carried out to confirm and determine the existence of a long-run relationship among the variables as specified in the equation.

Table 1: Augmented dickey fuller unit root test

Variables	ADF Statistics (Computed)		5% Critical Value		Remark
	Level	1st Difference	Level	1st difference	
Ln(ES)	-0.152036	-4.051919	-2.9422	-2.9446	1(1)
ln(TECH)	-3.237523	-	-2.9422	-2.9446	1(0)
ln(K)	-0.019352	-	-2.9422	-2.9446	1(1)
ln(PCGDP)	-1.727959		-2.9422	-2.9446	1(1)

** ln = log.

The Johansen cointegration test reveals that there is a long-run relationship between per capita gross domestic products (PCGDP) and other variables captured in the model. The result indicates two cointegrating equation(s) at 5 per cent and 1 per cent levels. The conclusion drawn from the result is that that there exists a unique long-run relationship between LOG(PCGDP), LOG(ES), LOG(K) and LOG(TECH). Since there are two cointegrating vector, an economic interpretation of the long-run on per capita gross domestic product in Nigeria can be obtained by normalizing the estimates of the unconstrained cointegating vector on per capita gross domestic product. The identified cointegrating equations can then be used as an error correction term (ECM) in the error correction model. This series will form the error correction variable, similar to the residuals generated when using the Engle-Granger two-stage method (Table 2).

Table 2: Johansen cointegration test for economic development equation.

Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesized No. of CE(s)
0.960825	175.2331	47.21	54.46	None **
0.689496	55.36335	29.68	35.65	At most 1 **
0.274206	12.08970	15.41	20.04	At most 2
0.006240	0.231594	3.76	6.65	At most 3

*(**) denotes rejection of the hypothesis at 5%(1%) significance level; Unrestricted Cointegration Rank Test
L.R. test indicates 2 cointegrating equation(s) at 5% significance level

Having established the extent and form of cointegrating relationships between the variables of the model, an over parameterized error correction model as shown in Table 3 was estimated. At this level, the over parameterized model is difficult to interpret in any meaningful way: its main function is to allow us to identify the main dynamic patterns in the model.

Table 3. Result of the over-parameterized model.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLnPCGDP(-1)	0.608617	0.402507	4.512064	0.1436
DLnPCGDP(-2)	0.112774	0.373884	1.301628	0.7655
DLnES	-0.012485	0.573239	-0.021779	0.9828
DES(-1)	0.011628	0.481480	-3.024152	0.0009
DLnES(-2)	0.384146	0.470219	0.816951	0.4220
DLnK	0.032600	0.076954	-3.423634	0.0056
DLnK(-1)	0.055986	0.060655	-2.613020	0.0097
DLnK(-2)	0.000330	0.072876	2.004531	0.0031
LnTECH	56.16646	106.7930	3.261778	0.0111
LnTECH(-1)	29.1510	57.05661	2.922502	0.2354
LnTECH(-2)	-6.425474	13.77421	-1.232870	0.0021
ECM(-1)	-0.600202	0.000307	5.657964	0.0003
C	0.100262	1.331739	2.075286	0.0406
R-squared	0.913676			
Adjusted R-squared	0.884901			
F-statistic	31.75268			
Durbin-Watson stat	2.174845			

*Ln = Log Dependent Variable: LOG(PCGDP)

But this study will be concerned with the parsimonious model that is more interpretable. Table 4 shows the result of the parsimonious model. From Table 4, the lagged value of per capita gross domestic product (PCGDP) is positive and conforms to economic theory. This implies that a 1 per cent increase in last year's PCGDP will lead to 0.763242 per cent increase in the PCGDP of the current or present year, ceteris paribus. Also, the coefficient of the lagged PCGDP is statistically significant at 5 per cent level.

Table 4: Parsimonious model for economic development Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLnPCGDP(-1)	0.763242	0.120218	6.348811**	0.0000
DLnES(-1)	0.005062	0.292552	6.503489**	0.0000
DLnK(-1)	-0.014813	0.060210	-0.246015*	0.8075
DLnK(-2)	0.011450	0.051631	2.221776**	0.0261
LnTECH	19.17554	21.07479	2.922501**	0.0014
LnTECH(-1)	I.638822	0.125260	2.826719**	0.0062
ECM(-1)	-0.580125	0.000174	3.71865**	0.0083
C	0.352723	1.020267	0.345716	0.7321
R-squared	0.810771			
Adjusted R-squared	0.734838			
F-statistic	57.16003			
Durbin-Watson stat	2.165077			

** = Significant at 5 per cent level; * = Not significant at 5 per cent level.
Ln = Log .

Also, the lagged value of electricity supply has a positive sign that is in line with economic theoretical expectation. The coefficient of lagged electricity supply is statistically significant at 5 per cent level. The implication of this result is that a 1 per cent rise in previous year's electricity supply will lead to 0.325062 per cent increase in the current per capita gross domestic product, all things being equal. This result further supports the study by Odell (1965) who investigated the role of electricity in a developing economy and concluded that electricity was very important for economic growth and development.

The coefficient of capital investment (K) lagged for 2 years is correctly signed and statistically significant at 5 per cent level. This means that an increase in the volume/value of capital investment for the last two years will enhance the rise in PCGDP by 0.011450 per cent, ceteris paribus. The coefficient of capital investment (not lagged) though correctly signed, is not statistically significant at 5 per cent level.

In the same table, the value of technology and its one year lagged value are contemporaneously positive and are all statistically significant at 5 per cent level. This means that an improvement in

technology over the years would definitely lead to increase in per capita gross domestic product. This result also supports the study by Ndebbio (2006) who advocated for improvement in technology as a means of overcoming the structural economic dimensions of underdevelopment. The strong significance of the coefficient of the error correction mechanism (ECM) supports our earlier argument that the variables are indeed cointegrated. The ECM shows a relatively high speed of adjustment (58 per cent) of the short-run and long-run equilibrium behavior of per capita gross domestic product (PCGDP) and its explanatory variables.

The adjusted R^2 shows that about 73 per cent of the total variation in per capita gross domestic product is determined by changes in the explanatory variables. Thus, it is a good fit. The F-statistics (57.16) indicates that all the variables are jointly statistically significant at 5 per cent level. The Durbin Watson statistics of 2.2 reveals that it is within the acceptable bounds, thus it is good for policy analysis.

Policy Implications and Conclusion

As has been stated, this study was conducted to analyze the interplay of electricity supply and economic development in Nigeria by correctly specifying the model. The Endogenous growth theory and the dead weight loss theory were reviewed. The model for estimation was derived from the Endogenous growth theory which was modified in line with the study. The estimation of the model was based on ordinary least squares in the context of error correction mechanism. From the linear regression results using ordinary least squares (OLS) method, the following can be deduced: In the economic development equation, all the variables captured in the model are correctly signed. Nevertheless, the lagged value of per capita gross domestic product, lagged value of electricity supply, technology and its lagged values and capital investment lagged for two years are the most reliable variables that significantly influence economic development in Nigeria. The policy implications of the result demands that more efforts should be geared towards the improvement of electricity generation and transmission technology in Nigeria and the various power projects should be completed with state of the art technology. The completion of power projects with state of the art technology in transmission and distribution of electricity will ultimately reduce power loss, manage consumption expansion crisis (reduce congestion) and boost electricity supply even in the face of an ever increasing population in Nigeria. The government should as a follow up to improvement in technology, also encourage capital formation and investment in (public) power sector by the private sector as this would boost electricity generation and supply and consequently economic development in Nigeria. Although the root causes of electricity supply inadequacy in Nigeria are not completely unfolded in this study but it has been established that adequate supply of electricity can engender economic development and these facts/finding(s) may as well serve as a basis for formulating policies to tackle electricity supply problems in Nigeria.

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