Multivariate Causality Test on Electricity Consumption, Capital, Labour and Economic Growth for Nigeria

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Abstract

This study examines the causal relationship between electricity consumption and economic growth in Nigeria from 1980 to 2008. The model is augmented with the inclusion of capital and labour as added regressors. Utilizing ARDL bound test to identify existence of long run interaction, we employ Granger causality test to identify causality among the variables and supplement the ARDL with FMOLS and DOLS to compute the long run estimates. Results suggest one-way causation flowing from electricity use to economic growth in Nigeria, in consonance with the findings of Akinlo (2009) and Squalli (2007) on Nigeria. Besides, the short run and long run estimates signify that electricity use is positively associated with economic growth, thereby reinforcing causality findings. The results generally call for energy expansionary policies. As the study also notes significant positive causality from capital and labour to economic growth, this means that beyond electricity consumption, capital and labour are the key determinants of economic growth in Nigeria.

Keywords: Economic growth, electricity consumption, bounds test, causality, structural break, Niger.

1. Introduction

Electricity as an energy source is an imperative infrastructure for modern

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economic setting. Adequate and reliable electricity is a major input for achieving socio-economic development by boosting productivity, facilitating basic human needs, alleviating poverty, creating jobs and ultimately improving quality of life. However, the Nigerian energy sector is among the most inefficient in meeting the demands of its customers (Iwayemi, 2008) as electricity consumption is too low for significant social and economic development. For instance, Nigeria's appallingly bad electricity supply aggravates production cost in the country by 40%, which forced many businesses to either fold up or relocate to other African nations and condemned the country to import even the necessity goods (The Presidency, 2011a). Therefore, the economic woes of Nigeria may be partly attributed to electricity problem. Given the positive correlation between poor economic condition and electricity problem in Nigeria, the real policy question lies on the flow of causality connecting electricity use and Nigeria's economy.

Research into the electricity-economy nexus has significant consequences on electricity development. A unidirectional causality flow from economic growth to electricity utilization implies that an economy is not totally reliant on electricity use for its growth, and that energy (especially electricity) conservation strategies can be executed with insignificant harmful consequence on economic growth. Similarly, evidence of no causality in either direction indicates that energy conservation strategies have no outcome on economic growth (Paul, and Bhattacharya, 2004). Conversely, unidirectional or bidirectional causality flowing from electricity utilization to economic growth means that such economy is reliant on electricity utilization, and a reduction electricity utilization may impede economic growth (Narayan, and Singh, 2007). However, causal flow connecting these variables in Nigeria is still much an ambiguity. For example, three studies dealing with Nigeria-Akinlo (2008), Squalli (2007), Wolde-Rufael (2006) provide different evidences for causation connecting electricity use and economic growth in Nigeria.

Hence, this study examines the flow of causation linking electricity use and Nigeria's economic growth from 1980 to 2008. Besides, the study addresses several issues raised by Akinlo (2009). These include the problem of infinite sample size; peril of omitted variable bias; and the possibility that use of Granger causality is susceptible to business cycle. On the issue of small sample size, unlike Akinlo (2009), this study utilizes a method- autoregressive distributed lag method (ARDL) bound testing which is robust in the presence of small sample size (Narayan, 2004). Moreover, we increase the sample size to 29 observations. On the problem of danger of omitted variable, the study increases the explanatory variables by providing for capital and labour force as against the bivariate analysis of Akinlo (2009). For Nigeria, this is also ideal because of gross underinvestment in the power sector, which has culminated in poor power supply and wiping out thousands of jobs; and it is forecasted that cost of Nigeria's unfortunate electricity supply would be 220 trillion naira, by 2020 (The Presidency, 2011a)[1]. On the possibility that Granger causality is associated with business cycle, the study further examines the long and short run elasticities of all explanatory variables on the economy. For robustness sake, the authors include two other estimators, which are the Fully Modified Ordinary Least Square (FMOLS) as advanced by Hansen and Phillips (1990), and Dynamic Ordinary Least Square lead/lag method (DOLS) as forwarded by Stock and Watson (1993) to supplement ARDL method. Furthermore, unlike the previous works on Nigeria, the study utilizes Zivot and Andrews (1992) method to endogenously establish structural shifts while conducting the unit root tests.

The rest of the paper is structured as follows. Section 2 provides a summary of electric power in Nigeria and Section 3 covers a brief literature review pertaining to electricity utilization and economic growth. Section 4 charts the methodology adopted in our paper while Section 5 provides empirical results and the last section completes the paper.

2. Overview of Electricity Sector in Nigeria

In Africa, Nigeria is the most populated country with a population in

[1] Current exchange rate is approximately 150 naira to a dollar.

excess of 155 million. The country is located in West Africa and borders Cameroon (1050 miles), Niger (930 miles) Benin (480 miles), and Chad (54 miles). Nigeria is 923,768 square km with landmass accounting for 910,768 sq km and water accounting for 13,000 sq km. Nigeria is richly endowed with natural resources, which include lead, zinc, petroleum iron ore, natural gas, tin, niobium, coal, limestone, arable land (CIA, 2011). Coincidentally, some of these natural resources are used in producing electricity in the Nigeria. These include hydropower, gas, oil and coal. The breakdown is contained in Table 1. The most vital sources of electricity in Nigeria include gas, which accounts for 56.64 percent and 67.17 percent of the total electricity generated in 1995 and 2007 respectively; and hydropower, which contributes around 30.24 percent and 33.78 percent in 1985 and 2005, respectively (WDI, 2010).

Table 1
Nigeria's Electricity Sources

Year	Coal	Hydropower	Gas	Oil
1980	0.00	38.77	43.57	17.66
1985	0.04	30.24	51.44	18.28
1990	0.10	32.59	53.65	13.67
1995	0.00	34.68	56.64	8.67
2000	0.00	39.00	54.06	6.94
2005	0.00	33.78	57.30	8.92
2007	0.00	27.88	67.17	4.95

Source: World Development Indicators (2010)

Accessibility to electricity is not only germane for economic development, but also raises the citizenry standard of living. Realising the importance of electricity to the social fabric of the society, the authorities in Nigeria have over the years rolled out policies to catch the attention of private sector, encourage investments; and engorge competition and efficiency in the power sector. Though electricity generation started in 1896 in Lagos, Nigeria (Sambo, 2008), actual reforms started few decades ago. For example, the Energy Commission of Nigeria (ECN) was created via Act No. 62 of 1979, and altered via Act No. 32 of 1988 and Act No. 19 of 1989, with the legislative objective of tactical scheduling and harmonization of national policies in the energy sector, inclusive of electricity policies (Sambo, 2008). Earlier, Nigeria's public electricity generating company- National Electric Power Authority – (NEPA) was established by government via Decree No. 24 of 1972. NEPA was a monopoly in the Nigeria's power sector. In order to break the monopoly of NEPA and encourage private sector investment particularly in generation and distribution, the government transformed NEPA to a less role-playing company- Power Holding Company of Nigeria (PHCN) in January 2004. In November 2005, the Nigerian electricity regulatory commission (NERC) was inaugurated for tariffs regulation and monitoring of the services of the PHCN. Other reforms include the creation of the Rural Electrification Fund (REF) to make electricity accessible to rural dwellers in a cost effective manner. Consumer Assistance Fund (CAF) was also instated to improve accessibility of the poor to electricity and protect consumers' interest (Ikeme, and Ebohon, 2005). The Fund is constituted by contributions from eligible consumers and customers; in addition other parties and federal government subsidies. In the following year, the Federal Government instituted an Advisory Committee on 25-Year Power Development Plan, to provide a realistic estimate of electricity demand over a 25-year period on which the power sector development would be based.

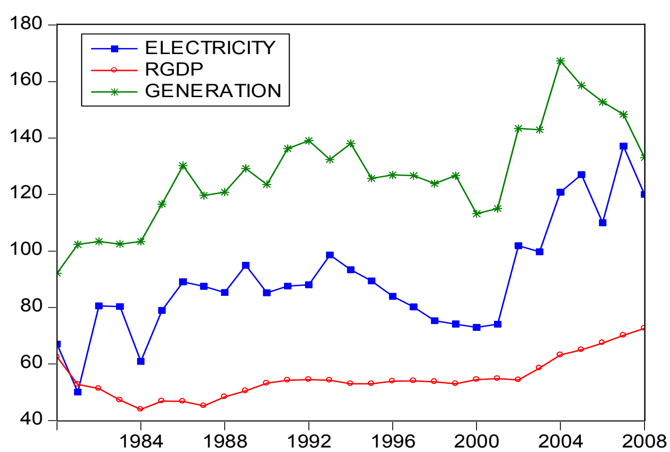

Fig. 1 Trend in Electricity Consumption, Generation and RGDP, 1980-2008

In spite of government efforts, electricity generation (GENERATION) fluctuated over the years. As shown in Fig. 1, electricity generation was 92.15 KWh per capita in 1980. This figure rose to 123.58 KWh per capita in 1990 and fell to 113.19 KWh per capita in 2000 before rising again to 167.26 KWh per capita in 2004, the year in which the government transformed NEPA to PHCN. In the year 2008, the figure stands at 133.12 KWh per capita. Conversely, electricity consumption (ELECTRICITY) rose over the years signifying the importance of electricity consumption in Nigeria. Electricity consumption was 67.053 KWh per capita in 1980 and rose to 85.177 KWh per capita in 1990 and further rose to 101.884 KWh per capita in 2002. In the year 2008, electricity consumption was 119.97 KWh per capita in Nigeria. The real gross domestic product (RGDP) is also reported in Fig. 1. Similar to the electricity generation the real gross domestic product per capita swung over the years, which can be attributed to changes in economic situation including electricity situation. For example, real gross domestic product per capita was around 62,000 naira in 1980 and decreased to about 53,000 naira in 1990 but increased to about 55,000 naira in 2000. The figure was 72,000 naira as at 2008.

The higher value of electricity generation over electricity consumption may lead to a pre-emptive assumption of no crisis of electricity in Nigeria. However, the problem of inadequacy of electricity remains visible in Nigeria. Severe energy crisis confronts the country due to diminishing electricity production from local plants which are chiefly defective, outmoded, undependable, in a dreadful poor condition, symbolising poor maintenance attitude in the country and the general ineptitude PHCN (Ikeme, and Ebohon, 2005). For example, in 2001, power produced declined from expected capacity of around 5.600 Gigawatt to approximately 1.750 Gigawatt, in comparison with to a load demand of 6.000 Gigawatt. Besides, just nineteen from the possible seventy-nine installed generating units were operational (Sambo, 2008). In 2004, vital manufacturing companies went through more than 300 power outages. The problem exacerbated by 26 percent in 2005 followed by a geometric 43 percent upsurge between 2006 and 2007 (Iwayemi, 2008). The country as a whole had a 47 percent electrification rate in 2008. In the same year, only 69 percent of the populace in urban areas had power supply, while accessibility of the dwellers was even worse with 26 percent electrification rate. Aggregately, more than 80 million in Nigeria do not have electricity supply (IEA, 2010). Resulting from government inability to provide electricity, many industries have closed down while some have relocated to neighbouring countries. The existing ones have continued to operate under harsh environment thereby raising the cost of production by over 30 percent. This has contributed to exorbitant rise in cost of commodities and loss of jobs. Even the purported 12 billion dollars invested into the power industry by Obasanjo regime failed in addressing the problem of power outages. It is alleged that the money went into the coffers of few privileged Nigerians who do not have the interest of the masses at hand (Thisday, 2010). From the foregoing, it is discernible that economy misery has been caused by and simultaneously strengthened electricity problem in Nigeria. In the subsequent section, the study reviews empirical studies on electricity use connection with economic growth.

3. Literature Review

In literature, there are extensive considerations of causations connecting electricity utilisation and economic growth, yet outcomes remain largely inconclusive. Starting with the empirical work of Kraft and Kraft (1978), the pattern of causation between energy utilisation and economic variables continues to generate intense controversies. This becomes obvious when considering various studies on each country or region. The conflicting results have not only extended to developing countries but also to investigating causation linking electricity use and various economies. Hence, we review literature specifically on electricity use and economic growth, highlighting contradictory results on country basis.

Starting with Turkey, Altinay and Karagol (2005) assess the pattern of causality between electricity utilization and income during 1950-2000, with Dolado-Lutkepohl method and causation test in Turkey. The two tests yield significant single causality flowing from electricity utilization to income.

Conversely, Halicioglu (2007) utilizes bound test and Granger causality test on electricity-growth nexus in Turkey for over the period 1968-2005. Estimates suggest long run causation flowing from economic growth to electricity utilization.

Variance of results does not confine to Turkey but extends to studies in Asian countries. For example, Yoo (2006) assesses the causation between electricity consumption and income on four ASEAN countries, including Malaysia and Singapore for the period 1971-2002. Using Granger causality test, the authors provide evidence for two-way causality between Singapore and Malaysia. Similarly, Tang (2008) provides evidence for two-way causation linking electricity utilization and Malaysia's economy. Conversely, Chen, Kuo and Chen (2007) conduct causality on 10 Asian countries including Malaysia and Singapore over the period 1971-2001. The results suggest single causality flowing from economic growth to electricity utilization in Singapore and Malaysia. Moreover, Yoo (2006) indicate one-way causality flowing towards electricity utilization from economic growth in Thailand, while Chen et al. (2007) observe no causality connecting electricity utilization and the economic growth in Thailand.

There are conflicting results on China. For instance, Shiu and Lam (2004) utilize Granger causality, Johansen cointegration tests for China to assess causation between electricity consumption and gross domestic product of China for 1971-2000. Findings signify the existence of a one-way causation towards economic growth from electricity use. Such finding is similar to observations of Yuan, Kang, Zhao and Hu (2008). Conversely, Chen et al. (2007) note no causation connecting electricity utilization and China's economy.

Moreover, the findings of Chen et al. (2007) demonstrate single causation from electricity use to income for Korea and India. However, Murray and Nan (1996) using Granger causality for the period 1970-1990, shows no causality connecting electricity consumption and India's economy. Moreover, Yoo (2005) in a study, which utilizes Johansen Cointegration test and Granger causality on Korea covering the period 1970-2002, provide contrary evidence. Against evidence of unidirectional causality, Yoo (2005) shows that dual causation exists between electricity utilization and economic growth in Korea. Hence, Yoo (2005) concludes that a rise in electricity utilization has direct impact on Korea's economy, which further stimulates electricity consumption in Korea.

Squalli (2007) investigates the relationship between electricity utilization and economic growth for members of Organization of Petroleum Exporting Countries (OPEC), including Indonesia for 1980-2003 period. The study adopts the bounds test for Cointegration and Toda and Yamamoto test (Toda & Yamaoto, 1995) for Causality. The results reveal a single causation from electricity utilization to economic growth in Indonesia. The finding is similar to Chen et al. (2007), but differs from Yoo (2006) that observe one-way causation from growth to Indonesia's electricity use.

In Pakistan, Jamil and Ahmad (2010) assess the association among electricity utilization, its price and economic activity at sector and aggregate stage in Pakistan. Utilizing yearly data for 1960-2008 period, Jamil and Ahmad (2010) note one-way causation from real economic activity to electricity utilization. Conversely, Aqeel and Butt (2001) reveal that single causation actually flows from electricity utilization to Pakistan's economy.

Beyond conflicting findings in Asian countries, researches on South American countries are also characterized with contradictory conclusions. Yoo and Kwak (2010) investigate causation connecting electricity utilization and economic growth among seven South American countries, which included Venezuela for the period 1975-2006. The authors utilize Hsiao version of the standard Granger causality test, among others to infer that causation linking electricity use and economic growth varies across countries. Results indicate dual causation linking electricity use and Venezuela's economy. In contrast Squalli (2007) reports single causation flowing from electricity to Venezuela's growth.

There are a small number of studies on African countries.

Notwithstanding, contrasting findings extend to studies on African countries. The most comprehensive study on Africa is Wolde-Rufae (2006) that considers causality between electricity and real gross domestic product for seventeen African economies, including Algeria. Findings suggest no causality connecting electricity consumption and the economy in Algeria. However, Squalli (2007) observes single causation from economic growth to electricity utilization in Algeria. Moreover, Odhiambo (2009b) consider causation test on South Africa data for the period 1971 to 2006. The findings suggest two-way causation between electricity utilization and economic growth in South Africa. This is contrary to Wolde-Rufae (2006) who obtains no causality result for South Africa.

In Nigeria, Akinlo (2009) assesses the causation connecting electricity consumption and Nigeria's income growth for the period 1980-2006, using Granger causality test, Johansen and Juselius (1990) cointegration test. The results illustrate cointegration between gross domestic product and electricity utilization and existence of single Granger causality to real gross domestic product flowing from electricity use. Squalli (2007) suggest similar findings. In contrast, Wolde-Rufae (2006) reveals single causality from economic growth to Nigeria's electricity utilization.

From the foregoing literature reviews, it is apparent that there are conflicting results for each country. This would create problems for policy makers on deciding the best action in regards to energy (electricity) policies. However, the quantum of results in favour of one hypothesis may persuade policy makers to choose a line of action. For example, in Nigeria, energy (and specifically electricity) conservation may be disadvantageous to Nigeria's economy as Squalli (2007) and Akinlo (2009) reveal single causality flowing from electricity utilization to Nigeria's economy. Therefore, energy expansion policy should be pursued. The adequacy of the studies in pursuing such decision is however questionable. Therefore, the current study re-examines the electricity utilization and Nigeria's economic growth.

4. Methodology and Data

4.1 Model

In exploring the electricity consumption and output interaction, the authors follow a neo-classical single sector aggregate production framework proposed by Ghali and El-Sakka (2004) who treats capital, labour, and energy (in our case, electricity) as separate inputs. This implies that:

$$RGDP_t = (CAPITAL_t \; LABOUR_t \; ELECTRICITY_t) \qquad (1)$$

Where $RGDP$ is real gross domestic product; $CAPITAL$ is Nigeria's capital stock; $LABOUR$ is Nigeria's total labour force; $ELECTRICITY$ is Nigeria's total electricity consumption, and subscript *t* symbolize time period. Differentiating Eq. (1) and dividing by $RGDP$ results in:

$$R\dot{G}DP_t = \alpha(CAP\dot{I}TAL)_t + \beta(LAB\dot{O}UR)_t + \gamma(ELEC\dot{T}RICITY)_t \qquad (2)$$

where the dot shows that each variable is in growth form. The parameters α, β and γ are elasticity of output with respect to capital stock, labour stock and electricity use, respectively. Production function (1) demonstrates that variables are related in the long-run (Ghali, and El-Sakka, 2004). Furthermore, for shortrun factor-input framework, specification in (2) imply previous changes in variables such as capital stock, labour force and electricity use contain valuable information in projecting future movements in output, ceteris paribus (Lorde, Waithe, and Francis, 2010). In other words, causality tests can be utilized to check the connection among the variables.

4.2 Data

We use yearly series for the period 1980 to 2008. Annual data for RGDP and CAPITAL are expressed in per capita and in local currency. ELECTRICITY consumption is expressed in KWh per capita. For the RGDP and CAPITAL, the nominal figures are converted to real terms using 2002

GDP deflator, before being divided by the population. LABOUR is the total labour force in Nigeria. As there is no data available on capital stock in Nigeria, we utilize net fixed capital formation (gross fixed capital formation minus inventories). Data on RGDP, LABOUR and ELECTRICITY (except for 2008 figure which is obtained from U.S. Energy Information Administration) are generated from World Development Indicators (WDI, 2010). CAPITAL (except the 1980 figure, which is obtained from the International Financial Statistics (IFS)) is obtained from statistical bulletin of central bank of Nigeria (CBN, 2009). In order to compute the variables' growth rates, we transform the variables into natural logarithm.

4.3 Stationarity Test

Traditionally, unit root tests using Augmented Dickey-Fuller (ADF) test as advanced by Said and Dickey (1984) and Phillip and Perron (PP) test as put forth by Phillip and Perron (1988) are employed to control for serial correlation when testing for stationarity. However, Perron (1989) shows structural change can considerably reduce the power of such tests and proposes unit root framework, with exogenous structural shift, which in turn has been criticized on the basis that it leaves room for arbitrary selection of dates. In response to Perron (1989) seminal paper on the impact of structural change on the power of conventional unit roots, authors develop several unit-root tests that consider incidence of structural changes. These works include Perron (1989) who propose unit root test with exogenous structural shift. However, the arbitrary selection of structural break date is a pitfall in the work of Perron (1989), and led Zivot and Andrews (1992) to advance sequential Dickey-Fuller test that most importantly considers the break dates as endogenous. In the process, Zivot and Andrews (1992) idealized three species of tests, which include unit root test of trend stationarity process with occurrence of a shift in trend (Model B) and a shift both in mean and trend (Model C).

$$\Delta Y_t = \mu_1^B + \beta_1^B t + \mu_2^B DT_t + \alpha^B Y_{t-1} + \sum_{j=1}^{k} c_j^B + \Delta Y_{t-1} + \varepsilon_t \quad (3)$$

$$\Delta Y_t = \mu_1^c + \beta_1^c t + \mu_2^c DU_t + \mu_2^c DT_t + \alpha^c Y_{t-1} + \sum_{j=1}^{k} c_j^c + \Delta Y_{t-1} + \varepsilon_t \quad (4)$$

where Δ represents first difference operator, T_B is the break date, DU_t and DT_t are respective dummies for shift in mean (level) and trend. $DU_t = 1$ if $t > T_B$, alternatively 0; and $DT_t = t - T_B$ if $t > T_B$, alternatively 0. Least *t*-statistic on the coefficient of the autoregressive variable ($t\alpha$) determines T_B.

4.4 Cointegration

Sequent to the stationarity test is Cointegration test in which we utilise bound tests of the ARDL approach as articulated by Pesaran and Shin (1999) and augmented by Pesaran, Shin and Smith (2001). There are abundant reasons for the adoption of this technique. As against the conventional Johansen cointegration method that uses a system of equations to estimate long run relationship, ARDL employs a singular reduced form model. Moreover, the test does not require pre-testing variables, hence it could be executed in spite of whether the series are integrated of order zero, one or are partially integrated, thereby reducing the task of establishing integration property of the variables. Moreover, estimator's long and short-run coefficients are simultaneously computed. As a result, failure to conduct hypotheses testing on Engle-Granger's method is circumvented. Besides, ARDL removes problems associated with omitted variables and autocorrelations; provides unbiased and efficient estimates (Narayan, 2004). Furthermore, it is compatible with studies based on small sample, as applicable in the present study. Procedurally, ARDL involves establishing long run connection employing Unrestricted Error Correction Models (UECMs) given as below:

$$\Delta \ln RGDP_t = \alpha_{10} + \sum_{i=1}^{p} \alpha_{11} \Delta \ln RGDP_{t-i} + \sum_{i=0}^{p} \alpha_{12} \Delta \ln CAPITAL_{t-i} + \sum_{i=0}^{p} \alpha_{13} \Delta \ln LABOUR_{t-i} + \sum_{i=0}^{p} \alpha_{14} \Delta \ln ELECTRICITY_{t-i} + \delta_{11} \ln RGDP_{t-i} + \delta_{12} \ln CAPITAL_{t-1} + \delta_{13} \ln LABOUR_{t-i} + \delta_{14} \ln ELECTRICITY_{t-i} + \varepsilon_{1t} \quad (5)$$

$$\Delta \ln CAPITAL_t = \alpha_{20} + \sum_{i=1}^{p} \alpha_{21} \Delta \ln CAPITAL_{t-1} + \sum_{i=0}^{p} \alpha_{22} \Delta \ln RGDP_{t-1} + \sum_{i=0}^{p} \alpha_{23} \Delta \ln LABOUR_{t-1} + \sum_{i=0}^{p} \alpha_{24} \Delta \ln ELECTRICITY_{t-1} + \delta_{21} \ln CAPITAL_{t-i} + \delta_{22} \ln RGDP_{t-1} + \delta_{23} \ln LABOUR_{t-i} + \delta_{24} \ln ELECTRICITY_{t-i} + \varepsilon_{2t} \quad (6)$$

$$\Delta \ln LABOUR_t = a_{30} + \sum_{i=1}^{p} a_{31}\Delta \ln LABOUR_{t-1} + \sum_{i=0}^{p} a_{32}\Delta \ln RGDP_{t-1} + \sum_{i=0}^{p} a_{33}\Delta \ln CAPITAL_{t-1} + \sum_{i=0}^{p} \alpha_{34}\Delta \ln ELECTRICITY_{t-1}$$
$$+ \delta_{31} \ln LABOUR_{t-i} + \delta_{32} \ln RGDP_{t-1} + \delta_{33} \ln CAPITAL_{t-i} + \delta_{34} \ln ELECTRICITY_{t-i} + \varepsilon_{3t} \quad (7)$$

$$\Delta \ln ELECTRICITY_t = a_{40} + \sum_{i=1}^{p} a_{41}\Delta \ln ELECTRICITY_{t-1} + \sum_{i=0}^{p} a_{42}\Delta \ln RGDP_{t-1} + \sum_{i=0}^{p} a_{43}\Delta \ln CAPITAL_{t-1}$$
$$+ \sum_{i=0}^{p} \alpha_{44}\Delta \ln LABOUR_{t-1} + \delta_{41} \ln ELECTRICITY_{t-i} + \delta_{42} \ln RGDP_{t-1} + \delta_{43} \ln CAPITAL_{t-i}$$
$$+ \delta_{44} \ln LABOUR_{t-i} + \varepsilon_{4t} \quad (8)$$

In the model equations (5), (6), (7) and (8), Δ represents first difference operator, ELECTRICITY is per capita electricity consumption, RGDP is Nigeria's gross domestic product per capita and CAPITAL is Nigeria's net capital formation per capita and LABOUR is Nigeria's total labour force.

Hence, combined significance test, which illustrates no cointegration

$$(\delta_{11} = \delta_{12} = \delta_{13} = \delta_{21} = \delta_{22} = \delta_{23} = \delta_{24} = 0:$$
$$\delta_{31} = \delta_{32} = \delta_{33} = \delta_{34} = 0: \delta_{41} = \delta_{42} = \delta_{43} = \delta_{44} = 0)$$

is conducted on (5), (6), (7) and (8). The F-test is considered in detecting existence of long-run connection among the series via testing the significance of the series' lagged terms. If calculated F-statistic surpasses upper critical value, then cointegration exists. The test is inconclusive, if the F-statistic lies within two bound of critical values. Finally, no cointegration, if critical value exceeds F-statistic.

4.5 Causality Test

Granger (1988) integrated the concept of Cointegration into causality. With cointegrated variables, Granger (1988) stated that causal relations among variables can be examined within the framework of the ECM. The short run information is summed up in lagged terms of individual series, while error correction term (ECT) contains information of long run causation. Hence, significance of lagged terms depicts short run causation. Conversely, negative and statistically significant ECT signifies long run causation. The equations are stated as below:

$$\Delta \ln RGDP_t = \alpha_{50} + \sum_{i=1}^{q} \alpha_{51} \Delta \ln RGDP_{t-1} + \sum_{i=1}^{q} \alpha_{52} \Delta \ln CAPITAL_{t-1} + \sum_{i=1}^{q} \alpha_{52} \Delta \ln LABOUR_{t-1} + \sum_{i=1}^{q} \alpha_{54} \Delta \ln ELECTRICITY_{t-1} + \varphi_1 ECT_{t-1} + \varepsilon_{5t} \quad (9)$$

$$\Delta \ln CAPITAL_t = \alpha_{60} + \sum_{i=1}^{q} \alpha_{61} \Delta \ln CAPITAL_{t-1} + \sum_{i=1}^{q} \alpha_{62} \Delta \ln RGDP_{t-1} + \sum_{i=1}^{q} \alpha_{62} \Delta \ln LABOUR_{t-1} + \sum_{i=1}^{q} \alpha_{64} \Delta \ln ELECTRICITY_{t-1} + \varphi_2 ECT_{t-1} + \varepsilon_{6t} \quad (10)$$

$$\Delta \ln LABOUR_t = \alpha_{70} + \sum_{i=1}^{q} \alpha_{71} \Delta \ln LABOUR_{t-1} + \sum_{i=1}^{q} \alpha_{72} \Delta \ln RGDP_{t-1} + \sum_{i=1}^{q} \alpha_{73} \Delta \ln CAPITAL_{t-1} + \sum_{i=1}^{q} \alpha_{74} \Delta \ln ELECTRICITY_{t-1} + \varphi_2 ECT_{t-1} + \varepsilon_{7t} \quad (11)$$

$$\Delta \ln ELECTRICITY_t = \alpha_{80} + \sum_{i=1}^{q} \alpha_{81} \Delta \ln ELECTRICITY_{t-1} + \sum_{i=1}^{q} \alpha_{82} \Delta \ln RGDP_{t-1} + \sum_{i=1}^{q} \alpha_{83} \Delta \ln CAPITAL_{t-1} + \sum_{i=1}^{q} \alpha_{84} \Delta \ln LABOUR_{t-1} + \varphi_4 ECT_{t-1} + \varepsilon_{8t} \quad (12)$$

where ECT is computed from the long run equation. From each equation, φ must produce a negative and significant sign for causality to exist in the long run. Armed with all the foregoing methods, the study provides the empirical findings in the following section.

5. Results and Findings

The results of ADF and PP unit root tests for RGDP, CAPITAL, LABOUR and ELECTRICITY are reported in Table 2. ADF and PP tests produce identical results for RGDP, CAPITAL and ELECTRICITY. The null hypothesis of nonstationarity is accepted for all the series in levels at even 10 percent level, but when series are first differenced, null of nonstationarity is rejected for all series at 10% level. For LABOUR, we reject the null hypothesis at levels but not at the first difference based on the PP tests. Thus, the results hint that RGDP, CAPITAL, LABOUR and ELECTRICITY are generally I(1).

Table 2
ADF and PP test

Variables	Levels		First differences	
	ADF	PP	ADF	PP
RGDP	-2.348	-2.349	-3.981**	-4.868***
CAPITAL	-2.331	-1.953	-6.434***	-4.692***
LABOUR	-1.567	-1.612	-1.619	-3.300*
ELECTRICITY	-2.076	-3.107	-5.700***	-8.046***

The lag selection of the ADF is based on AIC with lag length of 1.
The PP test is estimated based on quadratic Spectral kernel with Andrews bandwidth. Generally, the specification of tests includes intercept and trend; the authors based the critical values on Mackinnon (1996); and the null hypothesis is that of no stationarity. *, **, *** Imply stationarity at 10%, 5%, and 1% level of significance, respectively.

In Table 3, the auhors present the results of Zivot and Andrews (1992) model B and model C stationarity tests with incidence of one structural shift.

Table 3
Zivot-Andrews Test for Unit Roots

Variables	Model B		Model C	
	Z-A	Break	Z-A	Break
RGDP	-4.046	2003	-4.098	1999
CAPITAL	-3.445	2002	-3.402	2003
LABOUR	-3.985	2004	-3.922	1988
ELECTRICITY	-2.435	2001	-2.681	1997

The critical values for 1% and 5% levels are -4.930, -4.420 and -5.570, -5.080 for Model B and C from Zivot and Andrews (1992). The optimal lag is set to 2. The two models contain deterministic components. The null hypothesis is no stationarity with incidence of endogenous structural break.

The findings are akin to stationarity tests lacking structural shifts. Hence, this results into accepting the null hypothesis of stationarity at 5 percent level or better, affirming that all series are at least I(1). Shift periods for RGDP are 2003 and 1999, respectively. On the break dates for CAPITAL, the study notes 2003 for model B and 2002 for model C. Break dates for LABOUR of model B is 2004 and model C is 1988. Lastly, the break dates for model B and model C of ELECTRICITY are 2001 and 1997, respectively. These periods are associated with the transformation of Nigeria from a military-ruled to a democratic country.

The estimated F-statistic values displayed in Table 4 signify no long run connections, when CAPITAL and ELECTRICITY are dependent variables. Instead, cointegration exists when RGDP and LABOUR are dependent variables. For RGDP, this is noticeable because the computed F- statistic value of 11.372 with RGDP as the F-statistics of (11.372) is higher than upper bound critical value (5.615), at 1 percent significance level. With LABOUR as dependent variable, the computed F-statistic value of 4.264 exceeds the upper bound at 10 percent significance level. Hence, generally the study concludes that cointegration exists when the RGDP and LABOUR are dependent variables. The existence of cointegrating relationship RGDP, ELECTRICITY, LABOUR and CAPITAL indicates the existence of Granger causality relationship. Clearly, this suggests long run connection in the series,

Table 4
Bounds Tests Results

Dependent Variable	F-Statistics	10% I(0)	10% I(1)	5% I(0)	5% I(1)	1% I(0)	1% I(1)
RGDP	11.372***	2.711	3.800	3.219	4.378	4.385	5.615
CAPITAL	1.768	2.711	3.800	3.219	4.378	4.385	5.615
LABOUR	4.264*	2.711	3.800	3.219	4.378	4.385	5.615
ELECTRICITY	1.144	2.711	3.800	3.219	4.378	4.385	5.615

*, **, *** Imply 10%, 5%, and 1% level respectively. The critical values are for model with intercept but no trend, as contained in second case of Pesaran and Pesaran (1997). The null is no cointegration

when RGDP and LABOUR serve as dependent variables. Nevertheless, establishment of such linkages do not suggest flow of causation between series. Hence, in the next section a causality test is investigated.

Table 5
Causation Test

Dependent Variable	Granger Causality Results				
	ΔRGDP	ΔCAPITAL	ΔLABOUR	ΔELECTRICITY	ECT(-1)
ΔRGDP	-	2.495	1.431	31.081***	6.187***
ΔCAPITAL	7.197**	-	0.380	6.441**	-1.767*
ΔLABOUR	2.446	3.263	-	1.275	-
ΔELECTRICITY	0.399	0.327	1.810	-	-

Variables are in natural logarithm. Estimation period is 1980 to 2008. The chi-square statistics are reported for the variables, while the t-statistic is reported for the ECT. Due to initial serial correlation, the ARDL equation with ΔLABOUR as dependent variable is subjected to Newey-West adjusted Standard error with Tukey weights. The null hypothesis is no Granger causality. *, **, *** Imply 10%, 5%, and 1% level of significance respectively

The long run causation is investigated via the significance of lagged ECT. For testing short run causation, joint significance of lagged explanatory variables is employed according to Granger (1988). We present the causality findings in Table 5, which shows distinct one-way causation from ELECTRICITY to RGDP in short and long run. Long run causation from ELECTRICITY to RGDP is apparent because lagged ECT in RGDP function is negative and significant at 1 percent significance level. The short run causation is manifested due to significance of ELECTRICITY in the RGDP function at 1 percent significance level. The feedback causation from RGDP is on the other hand rejected in ELECTRICITY function. These results are akin to the observations of Halicioglu (2007) and Altinay and Karagol (2005) on, Turkey, Yoo (2005) on Korea, Yoo and Kwak (2010) on Brazil, Argentina, Columbia, Ecuador and Chile but contrary to Wolde-Rufael (2006) on Nigeria.

Turning to the other functions in the Granger causality test, the study observes long run causation from ELECTRICITY to LABOUR, as ECT in LABOUR function is significant at 10 percent significance level. As there is no feedback from ELECTRICITY, this implies single causality flowing from ELECTRICITY to LABOUR. Granger causality further indicates the existence of two-way causation between RGDP and LABOUR. For the CAPITAL function, in short run, single causation flows from ELECTRICITY to CAPITAL, at 5 percent significance level. On the other hand, while there is evidence for short run causation from RGDP to CAPITAL, in the long run causality flows from CAPITAL to RGDP.

From policymaking angle, the results can be subjected to economic interpretation and subsequently infer policy decisions on the association of electricity use and Nigeria's economy. According to Nayaran and Prasad (2007) one-way causation from electricity to growth implies that diminishing electricity utilization leads to a plunge in national income. Furthermore, lack of feedback from RGDP may mean that the focus of the economy in the electricity sector has not been adequate in Nigeria. Therefore additional income or economic growth has not translated into adequate capital investment in electricity sector as evident from the causality test, despite the importance of electricity. In reality, Nigeria has insufficiently invested in the electricity industry, which has grossly underperformed due to bad administration (The Presidency, 2011a).

Since the importance of electricity is a far reached conclusion (which is also buttressed above) on the economy, the Government and PHCN must implement policies that will spur the development of electricity sector in Nigeria. This includes massive capital investment in the electricity sector. In doing this, there should be private –public partnership, in which some areas of electricity sector, especially electricity generation will be privatized. The government should focus more on regulation, as effective regulation of the sector will induce quality standard, attract the right private investment and expand electricity infrastructure. Besides that, building other sources of power such as bio-power and solar power are viable alternatives. Evidently, developing alternative sources transcends beyond availability of capital but also the availability of appropriate labour force that will be in charge of stirring these sources as the sector has not been able to attract or retain best talents in the past (The Presidency, 2011b). Generally, these interpretations ignore the direction in which explanatory variables affect the dependent variables. Positive and significant signs, especially of the long run estimates of the impact of ELECTRICITY on RGDP validate the interpretations. In the next section, the study proceeds with the estimation of long and short run elasticities. Due to robustness concerns, ARDL long run estimates are augmented with the estimates of FMOLS and DOLS (Narayan, 2005).

Elasticities of ARDL, FMOLS and DOLS are presented in Table 6. In panel A of Table 6, the ARDL long run elasticities are presented along with the results of FMOLS and DOLS. Overwhelmingly, the results hint that CAPITAL, LABOUR and ELECTRICITY have positive impact on RGDP. ARDL estimates show that for every 1 percent increase in ELECTRICITY, the RGDP is to rise by 0.307 percent at 10 percent level. The other two estimates report positive impact of ELECTRICITY on RGDP, with better significance level. These findings reinforce the single causation from ELECTRICTITY to RGDP in the Granger causality test. CAPITAL (except in the ARDL estimates) and LABOUR have positive and significant effect on RGDP in the short run. It is estimated that CAPITAL, LABOUR and ELECTRICITY are also positively related in the long run. With these findings, policies aimed at improving the expanding energy (and electricity) facilities will improve the economy. In other words, energy conservation policies could hinder economic progress. In addition adequate capital and appropriate labour are also necessary for economics progress.

Beyond the robustness exercise of adding extra estimators, the study applies four diagnostic tests to the ARDL estimates in Table 7. The serial correlation test suggests no serial correlation in the error term. The functional form test hints that the model is rightly specified and there is no functional form problem. The model scales Jarque-Bera normality tests, indicating the model's errors are normal. Moreover, ARCH tests signify that errors are homoskedastic. Given that CUSUMSQ line does not stretch beyond the bounds of 5 percent level of significance in Fig. 2, the regression equation appears stable.

Table 6

Long run and Short run Elasticities

Panel A: Long run elasticities

Dependent Variable	ARDL				FMOLS				DOLS			
	RGDP	CAPITAL	LABOUR	ELECTRICITY	RGDP	CAPITAL	LABOUR	ELECTRICITY	RGDP	CAPITAL	LABOUR	ELECTRICITY
RGDP	-	0.092	0.534***	0.307*		0.178***	0.581***	0.157***	-	0.200**	0.527***	0.147**
CAPITAL	-	-	-	-	-	-	-	-	-	-	-	-
LABOUR	1.8917***	-0.496***	-	-0.369***	1.520***	0.308***		-0.142*	1.850***	-0.391***	-	-0.274***
ELECTRICITY	-	-	-	-	-	-	-	-	-	-	-	-

Panel B: Short-run elasticities

Dependent Variable	ΔRGDP	ΔCAPITAL	ΔLABOUR	ΔELECTRICITY
ΔRGDP	-	0.076**	0.226*	0.117**

All the variables are in natural logarithm. Estimation period is 1980 to 2008. FM-OLS and DOLS are based on Newey-West adjusted Standard error with Bartlett weights. *, **, *** Imply 10%, 5%, and 1% level of significance respectively.

Table 7
Diagnostics Tests

Test Statistics	LM test
Serial Correlation	CHSQ(1) = 0.334 [0.563]
Functional Form	CHSQ(1) = 0.104 [0.784]
Normality	CHSQ(2) = 0.839 [0.657]
Heteroscedasticity	CHSQ(1) = 2.303 [0.129]

These are the diagnostic results when RGDP is the dependent variable. These statistics are distributed as Chi-squared variates. The other equations are not reported here because of space essentially passed the diagnostics tests, with the exception of LABOUR as the dependent variable. This has been provided for with the use of Newey-west adjusted Standard error's as noted in the footnote of Table 2

6. Conclusion

This study assesses causation in Nigeria's electricity utilization and economic growth for the period 1980-2008. The model is supplemented with inclusion of capital and labour stock as supplementary regressors. Utilizing ARDL bound test to verify existence of long run connection, the study employs Granger causality test to detect causation among the variables and supplement the ARDL with FMOLS and DOLS to observe the long run coefficients of the estimates. Results suggest single short run and long run causation flowing from Nigeria's electricity use to economic growth, in line with the findings of Akinlo (2009) and Squalli (2007) but contrary to findings of Wolde-Rufae (2006) on Nigeria. Besides, short run and long run coefficients of three estimators (ARDL, FMOLS and DOLS) generally indicate that Nigeria's electricity consumption is positively associated with economic growth, thereby reinforcing causality findings.

This implies that policies aimed at decreasing Nigeria's electricity consumption could lead to degeneration in income level. In other words, electricity expansionary policies will improve the economy. These policies include creating other sources of power as such bio-power, nuclear power and solar power; instituting private-public partnership in the electricity sector so as to lure investors; solid regulatory framework and expanding electricity

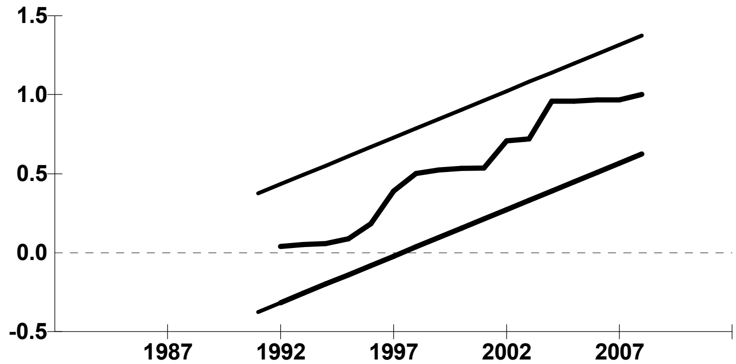

Fig. 2 Plot of Cumulative Sum of Square of Recursive Residuals

infrastructure. As the study note significant positive causality from capital and labour to economy, this means that beyond electricity consumption, capital and labour are the key determinants of economic growth in Nigeria.

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