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Electricity Consumption and Economic Growth Nexus: Evidence from Maki Cointegration

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The current study revisits the dynamic relationship between electricity consumption, real gross domestic product per capita and carbon dioxide emissions in Nigeria. To do this, we adopt the Zivot-Andrews (1992) unit root test to ascertain the stationarity properties of the interest variables. Maki (2012) cointegration test which accounts for multiple structural breaks is used for long-run equilibrium relationship between the variables while the long run regressions of dynamic ordinary least square (DOLS) and fully modified ordinary least square (FMOLS) for long-run coefficients as estimation techniques. The direction of causality is detected via the Toda-Yamamoto (1995) causality test for annual time series data from 1971–2014. Empirical evidence shows there exists a long-run equilibrium relationship between electricity consumption, real gross domestic product per capita and carbon dioxide emissions. The long-run regression suggests statistical significant and positive relationship between economic growth and electricity consumption. Thus, validating the electricity-induced growth hypothesis for Nigeria. According to the Toda-Yamamoto (1995) causality test, one-way causality is observed from electricity consumption to economic growth. This is in line with apriori expectation. However, there is an environmental implication of our study findings as electricity consumption spur increases carbon dioxide emissions. It is on the above premise that the study calls for diversification of Nigeria's energy portfolio to cleaner/environmental friendly sources like renewables.

Keywords: *Electricity Consumption; Economic Growth; Maki Cointegration; Dynamic Causality; Nigeria.*

Introduction

In recent times, the world has experienced energy shortage. This phenomenon is due to the abrupt increase in global energy demand (Sekantsi & Okot, 2016; Tamba *et al.*, 2017). This is because of the pivotal role energy (electricity) consumption plays in the stimulation of socioeconomic and economic activities of both developed and developing economies. The debate is still heated in the energy economics literature as to whether economic growth precedes energy consumption or vice versa. However, much has been documented in the energy economic literature for decades, mostly in developed economies. Little is known about this very interesting dynamic interaction in developing economies, more precisely in Sub-Saharan Africa (SSA). Thus, this current study focuses on Nigeria, which is faced with a huge and alarming electricity deficit. Recent statistics for the case of Nigeria reveal that an overwhelming 95,500,000 inhabitants of the population are without electrification, with 55 per cent of the total population without access to electricity while 45 per cent reside in urban centres and 63 per cent in rural areas (CIA, 2018). Given this backdrop, the country relies on load shedding to meet its electricity demand. Further, statistics shows that electricity consumption rose from 13.72billion Kwh in 2000 to 24.57 billion KWh in 2018 (CIA, 2018).

The persistent increase in electricity demand for economic activities in Nigeria, a fast-growing economy in West Africa, has become more severe and threatens to become more intense in the near future if prompt attention is not given to its energy sector. This highlighted electricity issue has drawn the attention of all stakeholders, ranging from energy economist, practitioners to government administrators, to mitigate these odds for increased economic growth. Thus, this study seeks to explore the nexus between electricity consumption and economic growth given its urgency and relevance to policymakers and government administrators.

This phenomenon has inherent policy implications. Thus, this current study seeks to fill this identified gap. It is against the above-mentioned backdrops that this current study seeks to bridge the identified gap for the case of Nigeria. This study contributes to the literature in the following ways: (i) in terms of its scope by including carbon dioxide emissions to our econometrics framework; our econometrics framework is trivariate rather than bi-variate, which is argued to be flawed with omitted variables (model misspecification), bias and a violation of the axioms of classical linear regression which previous studies investigated (Shahbaz & Feridun, 2012; Tamba *et al.*, 2017); (ii) in terms of methodological innovation because it leverages on structural break methodology given the nature of most macroeconomic/financial data, which previous studies fail to address.

For stationarity properties and asymptotic traits of series, this study uses the Zivot- Andrews (1992) unit root test, which accounts for a single structural break. For cointegration, the Maki (2012) cointegration test is used, which accounts for five structural breaks. Finally, for causal interaction, the Toda- Yamamoto (1995), which is a modified version of the Wald test (MWALD) for causality, is adopted, which is known to be more robust than the conventional Granger causality test. These structural break models were informed to avoid spurious analysis given breaks and jumps in the variables considered.

Literature Review

The debate is still heated in the energy economics literature as to whether economic growth precedes energy consumption or vice versa. This discussion was first introduced to the energy economics literature by the seminal studies of Kraft and Kraft (1978), where they investigated the causal nexus between energy consumption and economic growth for the United States. The study of Kraft and Kraft was an investigation of numerous studies (Akadiri & Akadiri, 2018; Akadiri *et al*., 2018; Emir & Bekun, 2018; Balcilar *et al*., 2010; Damette & Seghir, 2013; Narayan & Smyth, 2008). However, the literature can be classified into four strands, namely: those that claim that energy consumption drives economic growth (Damette & Seghir, 2013; Ghali & El-sakk, 2004); those that asserts that economic activities translate into higher electricity consumption, what is called in the literature conservative hypotheses (Baranzini *et al*., 2013; Jamil & Ahmad, 2010); the third group (Lee *et al.*,2008; Tang & Tan, 2013) is called the feedback hypothesis in the literature in which there exists a bi-directional causal relationship seen from both energy consumption and economic growth; and finally the fourth group (Halicioglu, 2009; Soytas & Sari, 2006) is known as the neutrality hypothesis where there is no causal interaction between energy consumption and economic growth.

More recently, several other studies are evident in the energy economic literature with diverse empirical outcomes. These discrepancies in the empirics could be attributed to the study area examined sampling and data collection procedures. More importantly, methodological and estimation techniques adopted. For single-country studies (see Wang *et al.*, 2017; Shahbaz *et al.*, 2017; Ameyaw *et al*., 2016; Hamdi *et al.*, 2014; Aslan, 2014; Belaid & Abderrahmani, 2013). Hamdi *et al*. (2014) explored the nexus between electricity consumption and economic growth for the case of the Kingdom of Bahrain while accounting for capital and foreign direct investment with the aid of Cobb-Douglas production function. Their estimations reveal cointegration (equilibrium) relationship between the variables. Hamdi *et al.*, (2014) study shows feedback causality between electricity consumption and economic growth. This position is also resonated in the empirical studies of (Aslan, 2014), for the case of Turkey. For the case of Ghana, using Cobb-Douglas growth production function is used to investigate the theme under review. Ameyaw *et al*. (2017) study give credence to the growth-led energy hypothesis. Thus, revealing that the Ghanaian economy is not energy-dependent. In China Wang *et al*. (2017), explore the nexus between economic growth and electricity consumption via a bootstrap causality approach, seemingly unrelated regression approach. Their empirical findings lend support to the economic growth induced electricity consumption. On the contrary, In Portugal Shahbaz *et al.* (2017) conducted a study and shows that the Portuguese economy is energy-dependent as unidirectional Granger causality is seen running from electricity consumption to economic growth. Their study also accounted for capital formation and financial development. More interestingly, for Turkey Nazlioglu *et al*. (2014), examined the theme under consideration via linear and non-linear estimators. Their study linear Granger causality supports the feedback causality in both the short and long run between electricity consumption and economic growth for Turkey. After filtering for non-linearity via the BDS non-linearity test. The nonlinear Granger causality test supports the neutrality hypothesis between the variables. Thus implying that Turkey can apply the conservative energy policy.

The other strands of studies conducted are a panel of countries. For instance the studies of Balsalobre-Lorente *et al.* (2018) for EU-5 countries namely (Germany, France, Italy, Spain and the United Kingdom). Balsalobre-Lorente’s study adopted the carbon emission production function to examine the theme for the aforementioned blocs. Their empirical study reveals renewable electricity consumption improve environmental quality while the study also controlled for trade openness, natural abundance, energy innovation and carbon dioxide emission. Kahouli (2018), examined Mediterranean countries (MC’s) for the nexus between electricity consumption and economic growth while controlling for carbon dioxide emissions and research development with the GMM, 3SLS and SUR econometrics methodology. Kahouli (2018) study lend supports to the electricity-induced growth. In the case of transition countries using bootstrap panel Granger causality test that accommodates for cross-sectional dependence and heterogeneity in the blocs investigated as conducted by Wold-Rufae (2014). The study found mixed results among the countries and offered requisites policy direction to the different countries. In a similar study carried out by Salahuddin (2015) examined the long-short run relationship between the theme under review for Gulf cooperation countries (GCC). The study submits to the robust relationship between the variables as well as establish the electricity-led growth hypothesis for the GCC over the period investigated.

Nigeria Energy Sector: A Brief

Nigeria is one of the largest economies on the sub-Saharan African (SSA) continent. Nigeria’s economy is topmost in oil production on the continent, followed by Angola. Nigeria holds high reserves of liquefied natural gas (LNG), also the country strives on oil production as the main source of foreign exchange earnings and revenue for the government (Wada, 2017a). Recent statistics from the US Energy Intelligence Agency (EIA, 2016) reveals that

Nigeria's economy relies heavily on her energy sector as a source of foreign exchange earnings, as, in 2014 the oil and gas sector accounted for 95 per cent of her gross exports to the rest of the world. However, in the global plunge in the oil price market, the country lost an alarming sum of 35 billion USD of her revenue. The explanation to this outcome also accounts for the unrest in the Niger Delta region of the country from where the oil is extracted. The Niger Delta region is also characterised by theft activities of gas pipeline networks installations and infrastructures by vandals. Also identified is poor management and corruption among government officials which has crippled the energy sector with a huge loss beyond the global oil price crash.

In recent times, the Nigeria energy sector has undergone a transformation and taken strides with the privatisation of the energy sector from the National Electricity Power Authority (NEPA) to the Power Holding Company of Nigeria (PHCH). More recent facts reveal that energy demand rose in Nigeria from 13.72 billion Kwh in 2000 to 24.57 billion Kwh in 2018 (CIA, 2018); this is due to the global energy demand and Nigeria is no exception.[1] Furthermore, the Nigerian government seeks to produce over 2000MW of energy from renewable energy sources which are known to be cleaner and environmentally friendly (NESP, 2015); the renewable alternatives will be from photovoltaic sources, wind and biomass. This milestone is projected to be the single largest in the world by 2030, accounting for more than half of total world output in 2040

The rest of this paper proceeds with Section 4, which presents the data and econometrics procedure while Section 5 focuses on empirical results and discussions. Finally, conclusion and policy implications form Section 6.

Data and Methodological Framework

Using annual data from 1971–2014 to explore the interaction between the electricity growth nexus for the case of Nigeria with data obtained from the CD- ROM of the World Development Indicator (WDI, 2018),[2] this study empirically follows Kayhan *et al*. (2010) and Wada (2017b) for empirical backing. Economic growth is proxy as real gross domestic product per capita constant 2010 USD (PGDP), carbon dioxide emission (CO_2) in Kt as indicator for environmental degradation and electricity consumption (EC) in kWh per capita

Model Specification

The functional relationship between electricity consumption, carbon dioxide emissions and economic growth can be presented as follows:

$$ELE = f(PGDP, CO_2) \quad (1)$$

To achieve homoscedasticity, logarithm transformation is carried out in equation 1

$$LnELE = \alpha + \beta_1 LnPGDP_t + \beta_2 LnCO_2 + \varepsilon_t \quad (2)$$

Here, α signifies constant and $\beta_{1,}\beta_2$ are partial slope parameter. Also, LnELE, Ln PGDP and $LnCO_2$are the natural logarithms for real gross domestic product per capita (PGDP), electricity consumption (ELE) and carbon dioxide emissions (CO_2).

Stationarity Test

In time series econometrics analysis, the need for stationarity test is essential to avoid spurious analysis. The econometrics literature houses numerous unit root and stationarity tests, among which are Augmented Dickey-Fuller (ADF) (1981) Phillips & Perron (PP) (1988). However, most of the well-known tests do not capture for structural breaks. Given the nature of most macroeconomics/finance data, it is possible to claim that analysis made on such dataset is spurious if structural break(s) is not accounted for. It is on this premise that the current study adopts the relatively new Zivot and Andrews (1992) unit root test that ameliorates for the mentioned shortcoming. The Zivot and Andrews (ZA, hereafter) accounts for single structural break with null hypothesis of unit root (non-stationary) against an alternative of Stationarity.

Cointegration Test

Most macroeconomics/finance theories or postulates are based on equilibrium framework. Thus, the need of a cointegration test is vital to aid establish long-run bound among series. The traditional cointegration test (see Johansen, 1991;Johansen & Juselius, 1990) fail to account for structural break(s). Thus, new breeds of cointegration test are available in the econometrics literature that help circumvent for spurious analysis and help account for the breaks (Gregory & Hansen, 1996; Westerlund & Edgerton, 2007). The mentioned test interestingly accounts for single structural break. Given the nature of the macroeconomic variable it is arguable that such estimators are flawed. Thus, this study employs Maki (2012)[3] cointegration test, which accounts for multiple structural breaks. The equations for Maki (2012) are given as:

Model I: Break in intercept and without trend

$$z_t = \mu + \sum_{i=1}^{m} \mu_i D_{i,t} + \delta' x_t + u_t \quad (3)$$

Model II: Break in intercept and coefficients and without trend

[1] For readers interested in the energy consumption demand chart, see the CIA web link below: https://www.indexmundi.com/g/g.aspx?c=ni&v=81

[2]The data available for CO_2 and electricity were available till 2014, while RGDP was available till 2017, but the data choice of 1971–2014 was to ensure balance in the data set and to ease estimation

[3]The authors are grateful to Prof. Daiki Maki of the Faculty of Economics, Ryukoku University for the availability of the codes in GAUSS that facilitated simulation of the cointegration results

$$z_t = \mu + \sum_{i=1}^{m} \mu_i D_{i,t} + \delta' x_t + \sum_{i=1}^{m} \delta_i' x_t D_{i,t} + u_t \qquad (4)$$

Model III: Break only in intercept and coefficients, but model has trend

$$z_t = \mu + \sum_{i=1}^{m} \mu_i D_{i,t} + \beta t + \delta' x_t + \sum_{i=1}^{m} \delta_i' x_t D_{i,t} + u_t \qquad (5)$$

Model IV: Break in intercept, coefficients and trend

$$z_t = \mu + \sum_{i=1}^{m} \mu_i D_{i,t} + \beta t + \sum_{i=1}^{m} \beta_i t D_{i,t} + \delta' x_t + \sum_{i=1}^{m} \delta_i' x_t D_{i,t} + u_t \qquad (6)$$

Here, the D_i is a dummy, where $D_{i}=1$ when $t > T_b$ and $D_i=0$, where T_b indicates possible break point.

Estimation of Long-Run Coefficients

Long-run equilibrium coefficients become necessary after the establishment of cointegration relationship among the variables under review. To this end, dynamic ordinary least squares (DOLS) and fully modified least squares (FMOLS) estimation tests are employed to determine the magnitude of long-run equilibrium. The merits of the DOLS include that the DOLS can be estimated regardless of the order of integration of series, but the dependent variable is expected to be integrated of order one. Also, DOLS helps to circumvent for serial correlation problem estimation of the model and other internalities (see Esteve & Requena, 2006).

The formula for DOLS model is given as:

$$\ln ELE = \beta_0 + \beta_1 \ln CO_{2,t} + \beta_2 \ln PGDP_t + \sum_{i=-q}^{q} \varphi_i \Delta \ln CO_{2,t-1} + \sum_{i=-q}^{q} \gamma_i \Delta \ln PGDP_{t-1} + \mu_t \qquad (7)$$

where q represents the optimum lag level as suggested by Schwarz Information Criterion.

Causality Test

Traditional causality does not connote causation. Thus, a causality relationship is essential given the inherent policy implication that can be gleaned from such analysis. This study adopts the Toda-Yamamoto (1995) causality technique for predictive power among variables. The Toda-Yamamoto causality test (TY hereafter) is a modified fashion of the Wald test (MWALD). The TY causality test has pertinent advantages over the conventional Granger causality test. TY causality is known to have more resilience. Furthermore, beyond being resilient, TY approach is peculiar in the sense that it can be estimated regardless of the order of integration of variables considered. The technique is structured in a Vector Autoregressive framework VAR with (K+ d_{max}) where, K is the optimal order of integration in the VAR and d_{max} is the maximum integration order.

The VAR (K + d_{max}) is given as:

$$\ln ELE = \beta_0 + \sum_{i=1}^{m} \beta_{1i} \ln ELE_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{1j} \ln ELE_{t-j} + \sum_{i=1}^{m} \alpha_{1i} \ln CO_{2,t-i} + \sum_{j=k+1}^{d_{max}} \alpha_{2j} \ln CO_{2,t-j} + \sum_{i=1}^{m} \delta_{1i} \ln PGDP_{t-i} + \sum_{j=k+1}^{d_{max}} \delta_{2j} \ln PGDP_{t-j} + \varepsilon_{1t} \qquad (8)$$

$$\ln CO_2 = \alpha_0 + \sum_{i=1}^{m} \alpha_{1i} \ln CO_{2,t-i} + \sum_{j=k+1}^{d_{max}} \alpha_{2j} \ln CO_{2,t-j} + \sum_{i=1}^{m} \beta_{1i} \ln EC_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{2j} \ln ELE_{t-j} + \sum_{i=1}^{m} \delta_{1i} \ln PGDP_{t-i} + \sum_{j=k+1}^{d_{max}} \delta_{2j} \ln PGDP_{t-j} + \varepsilon_{2t} \qquad (9)$$

$$\ln PGDP = \delta_0 + \sum_{i=1}^{m} \delta_{1i} \ln PGDP_{t-i} + \sum_{j=k+1}^{d_{max}} \delta_{2j} \ln PGDP_{t-j} + \sum_{i=1}^{m} \alpha_{1i} \ln CO_{2,t-i} + \sum_{j=k+1}^{d_{max}} \alpha_{2j} \ln CO_{2,t-j} + \sum_{i=1}^{m} \beta_{1i} \ln ELE_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{2j} \ln ELE_{t-j} + \varepsilon_{3t} \qquad (10)$$

Empirical Results/Discussions

This section provides the empirical estimations and results. Figure 1 provides the visual plots of the series which conspicuously shows points of possible breaks. The break years reflect political and economic episodes in the country under investigation. Thus, this study uses estimators that account for such breaks in order to avoid spurious analysis.

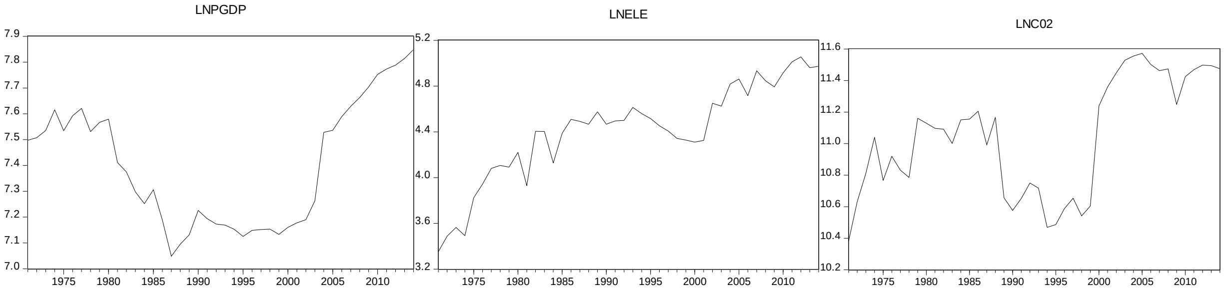

Figure 1. Visual Plots of Series under Review

Table 1

ZA (1992), Tests for Unit Root under a Single Structural Break

	Statistics (Level)			Statistics (First Difference)			
	ZA_I	**ZA_T**	**ZA_B**	**ZA_I**	**ZA_T**	**ZA_B**	**Conclusion**
*ln*ELE	-3.68	-4.13	-3.28	-8.33*	-6.62*	-8.58*	I (1)
Time Break	1995	1995	1995	2002	1997	2002	
Lag Length	1	0	1	1	1	1	
$lnCO_2$	-5.51	-3.21	-5.15	-7.63*	-6.98*	-8.12*	I (1)
Time Break	2000	1995	2000	1996	1988	2000	
Lag Length	1	1	1	1	1	1	
lnPGDP	-2.92	-3.30	-3.13	-7.34*	-7.35*	-7.46*	I (1)
Time Break	2004	1995	1994	1978	1982	1988	
Lag Length	1	1	1	1	1	1	

*Note: Ln ELE is electricity consumption, CO_2 is carbon dioxide emissions and PGDP is real gross domestic product per capita. All of the variables are at their natural logarithms. ZA_I represents the model with a break in the intercept; ZA_T is the model with a break in trend; ZA_B is the model with a break in both the trend and intercept. * indicates significance at the 1 per cent level.*

Table 1 above reports the Zivot-Andrews (1992) unit root test suggesting that all the data series are non-stationary at level form. However, after first differencing all series under review became stationary when a single break was allowed. Thus, all series are integrated of same order ~ I(1). Results in Table 1 prompt the need for a structural break cointegration test such as the Maki cointegration test as the most appropriate for long-run equilibrium relationship with null hypothesis of no cointegration against an alternative of cointegration. The cointegration test is presented in Table 2. The result depicts the existence of a long-run equilibrium relationship between electricity consumption, CO_2 emissions and real gross domestic product per capita under multiple structural breaks. The cointegration test under multiple structural breaks, as reported by Maki cointegration, shows several break years. This break year reflects both political and financial instability episodes experienced in Nigeria. Among such is in year 1999, as reported in our Maki result. Nigeria had its first democratic government rule and this had its implication on the energy sector. Similarly, 2007 also birthed another political regime. However, Nigeria's electricity power development is dated to the 1950s with the Electricity Corporation of Nigeria (ECN) while 1973 saw the birth of Nigeria Electric Power Authority (NEPA), a merger between ECN and Niger Dam Authority.

Several reforms were enacted to salvage the country's epileptic electricity supply and general energy sector, especially in the late 2000s; during this period, NEPA became a public limited company and the name was once again transformed to the Power Holding Company of Nigeria (PHCN). In 2013, the wave of privatisation also had its toll on the energy sector with the privatisation of PHCN and transformation to the Nigeria Electricity Regulatory Commission (NERC) which was saddled with the mandate of generation and distribution of energy. All the above data are captured in Table 2 in regards the implications. Similarly, financial instability, such as the global financial crisis years, 2006–2009, was seen in the break years. There is a strong correlation between financial stability and economic growth. This assertion is validated by conventional wisdom and empirical intuitions.

Furthermore, this study investigates the effect of privatisation of the electricity sector on economic growth. By conducting a restricted regression before and after the privatisation episodes, the partial effect of per capita GDP and CO_2on electricity consumption are evident. Table 3 presents the restricted regression. The study reveals a positive and significant impact of privatisation on electricity consumption, as seen in Table 3. Although prior to privatization has a positive effect as well as after on electricity consumption. Interestingly, our study shows that carbon dioxide emission is less in effect before privatization relative to after privatization. This is revealing and indicative to environmental economists. This implies that private venture installations are not environmental friendly. Thus, adequate sanctions should be applied by government authorities to switch to more environmentally friendly plants and installations.

Strikingly and unexpectedly our study found less impact of per capita GDP after privatization relative to before privatization on electricity consumption in Nigeria. The possible explanation for this phenomenon could be the newly introduced prepaid meters for energy consumers. Thus, implying regulation on the demand side for energy (electricity) consumption. Although over the years, Nigeria power sector has suffered challenges that impede optimal delivery of power to her citizens. The country is known to have failed in her vision 20:2020 and her renewable energy master plan as well as the joint efforts of energy commission of Nigeria and the united nation development program. The plausible answer to these is captured in the studies of (Ajayi & Ajayi, 2013), were poor willpower from the government, lack of incentives and multiple taxations as well as unfavorable custom duties crowded out investors to her energy sector and the realization of her renewable energy dreams. Poor and weak legal laws to aid the quest was also highlighted. This is a wake-up call for the government to be more committed to her energy commitment for national development.

Model: $ELE = f(PGDP, C02)$[4]

Table 2

Maki Cointegration Test under Multiple Structural Breaks

Number of Break Points		Test Statistics [Critical Values]	Break Points
TB≤5			
	Model 0	-7.18[-5.76]*	1987;1989;1999;2003;2007
	Model 1	-7.51[-5.99]*	1973;2003;2008;2010;2012
	Model 2	-7.88[-7.28]*	1980;1986;1990;2007;2011
	Model 3	-8.53[-8.12]*	1978;1988;1995;2001;2006

Note: numbers in [ ] denotes critical values at 0.05 level obtained from Maki's (2012) generic article while
** signifies statistical significance at 0.01 significance level.*

Table 3

Estimation Results Before and After Privatisation

Variables	Before privatisation		After Privatization	
	DOLS	FMOLS	DOLS	FMOLS
LnPGDP	1.142(0.000)***	1.677(0.000)***	0.658(0.009)***	0.765(0.000)***
LnCO2	0.139(0.627)	0.309(0.189)	1.058(0.029)**	0.715(0.000)***

Note: ( ) are P-value.

Table 4

Cointegration Coefficients

Variables	DOLS	FMOLS
LnPGDP	0.198(0.084)*	0.699(0.019)**
LnC02	0.467(0.215)	0.085(0.417)

*Note: ***,**,* denote rejection at 0.01,0.05 and 0.1 significance level respectively. while numbers in ( ) are P-value.*

Furthermore, this study proceeds to investigate the magnitude of the cointegration via dynamic ordinary least square (DOLS) and fully modified ordinary least square (FMOLS) regression for the full sampled period. Table 4 shows that both per capita GDP and CO_2 contribute positively and exert an inelastic effect on electricity consumption. GDP per capita contributes significantly positively to electricity consumption in Nigeria. That is, a 1 % increase in economic activities birth a corresponding 0.19 % and 0.69 % for DOLS and FMOLS respectively increase in electricity consumption. However, carbon dioxide emissions contributes positively though not significant. This implies that the nation emission is yet to reach the intolerable threshold. This is indicative to energy and environmentalist that formulate and design energy regulations/laws. This is necessary given the global awareness toward cleaner and renewable energy sources. This position is strengthen in the studies of (inter alia Shahbaz *et al.*, 2012; Balsalobre *et al.*, 2018). Our study position corroborates the finding of (Akinwale *et al.*, 2013; Agbaje & Idachaba, 2018) for the case of Nigeria.

Subsequently, this study proceeds to account for the directional causality among series through the Toda-Yamamoto (1995) causality test. Table 5 provides the TY causality results. There exists unidirectional causality running from electricity consumption to carbon dioxide emissions. Also seen is unidirectional causality running from electricity consumption to economic growth, which is very insightful in the study area. Thus, this study validates the electricity-led growth hypothesis for the case of Nigeria. Thus, affirming that the Nigerian economy is energy (electricity)-dependent. Our findings corroborates with findings of Shahbaz *et al.*, (2017) for Portuguese economy. Thus, the revelation of the Nigerian economy being electricity-dependent implies that a conservative policy would have negative effect on its economic growth. That is, caution should be taken while designing energy policy and implementation. However, no causal interaction is observed running from carbon dioxide emissions and per capita GDP, or vice versa, for this study.

[4] As suggested in Maki's (2012) generic paper, four models were provided: (1) breaks at level shift; (2) level shift with trend; (3) regime shift; (4) trend and regime shift. This study reports model 4 with trend and regime shift for the brevity of space as other models are in harmony of cointegration relationship among the investigated series. The rest can be made available upon request.

Table 5

Toda-Yamamoto (1995) causality test

Hypothesis	Chi-square P-value	Decision
lnELEC does not cause *lnCO*$_2$	0.01**	Reject
lnCO$_2$ does not cause *lnELE*	0.28	Fail to Reject
lnPGDP does not cause *lnELE*	0.02	Fail Reject
lnELE does not cause *lnPGDP*	0.38**	Reject
lnCO$_2$ does not cause *lnPGDP*	0.79	Fail to Reject
lnPGDP does not cause *lnCO*$_2$	0.13	Fail to Reject

*Note: ** indicates 5 per cent significance level.*

Residual Diagnostic Test

The result of the residual diagnostic test is presented in Table 6.

Table 6

Residual Diagnostic Test

Normality			
Jarque- Bera	2.646712		(0.266)
Breusch-Godfrey Serial Correlation LM Test			
F-stat	1.901	Prob. F(2, 29)	(0.129)
White Heteroscedasticity Test: White			
F-stat	1.809	Prob. F(2, 38)	(0.134)

Note: () are probabilities numbers

Table 6 presents the diagnostic test for this study; from the above estimates, the model selected for this study is normally distributed, as reported by the Jarque Brea Normality test, and this study model is also free from serial correlation and heteroscedasticity. The CUSUM and CUSUMsq plots were found between the 95 % confidence interval, thus, confirms the stability of the fitted model. This indicates that the model for this study is fit and robust for model policy direction in Nigeria.

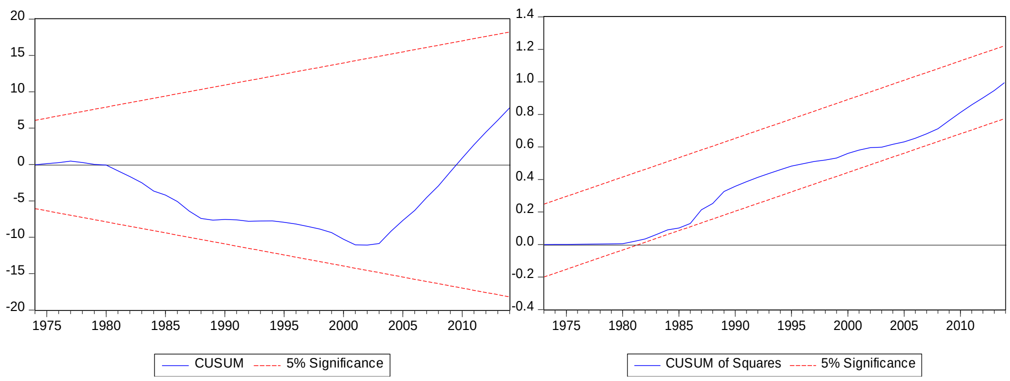

Figure 2 and 3. Renders the CUSUM and CUSUM for Model Stability

Concluding Remarks/Policy Implications

This country-specific study validates the electricity-induced growth for the case of Nigeria using annual data from 1971–2014. Data were retrieved from the WDI CD-ROM (2018). This study is conducted in a trivariate framework as against previous studies conducted in a bivariate frame work. This study's novelty lies in methodological innovation and by scope with the inclusion of CO_2 in the econometrics framework. The unit root test according to Zivot-Andrews (1992) unit root test under single structural break depicts that all series are stationary after first difference, while, for equilibrium relationship, Maki (2012) is adopted for cointegration relationship and, for causal interaction, Toda-Yamamoto (1995) causality was employed.

The study finds equilibrium relationship between electricity consumption, real gross domestic product per capita and carbon dioxide emissions according to the Maki cointegration test. The causality test indicates uni-directional causality between electricity consumption to economic growth validating the electricity-led growth hypothesis. This outcome is in line with the findings of Shahbaz *et al* (2017) for Portuguese economy. Thus, conservative policies cannot be implemented without deteriorating impact on the economy. The above finding further reveals that the Nigerian economy is energy-dependent. Similarly, as revealed by the TY causality test, the electricity-induced carbon dioxide emissions resonates with the findings of Itodo *et al*. (2017). Furthermore, unidirectional causality is seen running from electricity consumption to CO_2 emissions, which implies a tradeoff between industrialisation and electricity consumption in Nigeria.

In summary, the findings of this study and possible implications are:

There is need for policy makers in Nigeria to raise economic activity by enhancing electricity consumption as a stimulus for economic growth. This can be achieved via the following routes, namely, (a) effective electricity generation and distribution to all areas and (b) optimum electricity tariff to induce more electricity consumption; however, this action can crowd out investors and investment in the energy sector, so an optimal tariff is encouraged.

Also, a unidirectional causality from electricity consumption to CO_2 calls for the attention of policy makers and environmental specialists to design environmentally friendly strategies like the Kyoto-Protocol agreement, which Nigeria is not yet part of.

In conclusion, the need for policy makers to diversify the energy portfolio to other sources of energy that are environmentally friendly, such as photovoltaic energy, biofuel and wind energy, is crucial at a time where the entire globe is clamouring for a clean society. This is further resonated in the studies of Ajayi and Ajanaku (2009) of the laudable role energy especially renewable energy availability, its supply, demand and use play as a key determinant of national development. Thus, policy makers are encouraged to take pragmatic strides to the energy sector rather than mere lip service, if the full gains are to be gleaned from the energy sectors as seen in other economies.

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