Electricity consumption and economic growth in Nigeria: A revisit of the energy-growth debate

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Electricity Consumption, Inflation, and Economic Growth in Nigeria: A Dynamic Causality Test

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Abstract

This paper examines the dynamic causal linkages between electricity consumption and economic growth in Nigeria within a trivariate VECM, for the period 1971-2012. The paper obviates the variable omission bias, and the use of cross-sectional techniques that characterise most existing studies. The results show that there is a distinct causal flow from electricity consumption to economic growth: both in the short run and in the long run. This finding supports the electricity-led growth hypothesis, as documented in the literature. The paper urges policy-makers in Nigeria to implement policies which enhance the generation of electricity in order to engineer economic growth. Appropriate monetary policies must also be put in place, in order to moderate inflation, thus enhancing growth.

Keywords: Electricity Consumption, Economic Growth, Inflation, Cointegration, Causality, Nigeria

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1. Introduction

One of the most examined issue in growth literature, recently, is the causal link between electricity consumption and economic growth.[2] The modern day climate change, energy crises, rising prices of crude oil, and the ever-growing emission of carbon in to the atmosphere have added momentum to the debate. The ability to establish the exact causal pattern between electricity consumption and economic growth is of immense relevance to policy formulation, especially for countries such as Nigeria which rely heavily on electricity as their sole source of energy.

Empirical support for electricity-led growth would imply that conservation policies could be disastrous for economic growth, which inherently enhances poverty, and reduces both job creation and societal welfare (see Ghosh, 2002, and Odhiambo, 2009). Further, if economic growth Granger-causes electricity consumption, then there might be little to worry about when implementing electricity-related conservation policies (see for instance, Asafu-Adjaye, 2000, Narayan and Smyth, 2005).

The pioneering work of Kraft and Kraft (1978) triggered the interest in the energy consumption-growth debate. Since then, the debate has been extended to specifics, such as the electricity-growth nexus, clean energy-growth, and other related issues. Until this point in time, the energy consumption and economic growth debate had produced conflicting and interesting outcomes. Previous research on this debate was widely conducted for countries in

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[2] The original debate was whether energy consumption causes economic growth or economic growth causes energy consumption. The over-reliance of certain economies on electricity—a component of energy—has compelled researchers to narrow the debate to specifics. This work follows suit, since Ghana is more electricity dependent; albeit, the use of oil cannot be discounted (see Lee, 2005, for a broad debate).

Latin America, the Caribbeans and Asia; however, few concentrated on the countries in sub-Saharan Africa (see Odhiambo, 2009); and Nigeria's case has been even less researched.

Our extensive search shows that Lee (2005), Wolde-Rufael (2006), and Akinlo (2008) are the only available literature on the electricity consumption and economic growth debate on Nigeria. Besides, most of these studies suffer from two main limitations: a) Omission-of-variable bias, when testing for causality within a bivariate VAR (see Murray and Nan, 1996; and Yoo, 2005); and b) and over-reliance on cross-sectional data to explain country-specific issues (see Murray and Nan, 1996; and Wolde-Rufael, 2006). This paper overcomes the limitations stated by employing a trivariate vector error-correction model (VECM) to examine the causal linkages between electricity consumption and economic growth. Specifically, the paper incorporates inflation as an intervening variable that influences both electricity consumption and economic growth. It has been argued that if such a variable is included in the causality framework, the direction of causality could not only change, but the magnitude might also increase (see Caporale and Pittis, 1997; Odhiambo, 2008; and Njindan, 2013).

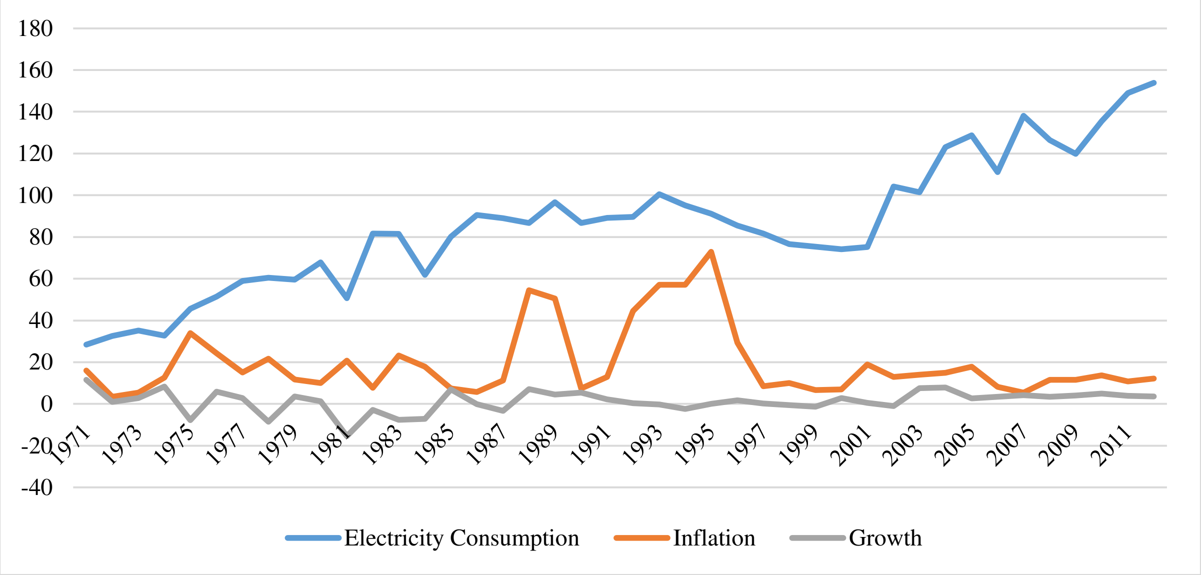
The remaining sections of this paper are organised as follows: Section 2 provides an overview of the trends in electricity consumption, inflation, and economic growth in Nigeria; Section 3 discusses the relevant literature on the electricity-growth debate; Section 4 presents the methodological issues, the empirical estimations and the analysis; while Section 5 provides the conclusions.

2. Electricity Consumption, Inflation, and Economic Growth Trends in Nigeria

Nigeria has struggled to provide electricity to its large population ever since independence. According to Nigerian Electric Power Authority (NEPA), the Niger Dam has the maximum capacity to generate 5,900 megawatts of electricity per day which falls far below the average national consumption rate of 10,000 megawatts per day. This has compelled NEPA to ration electric power supply over the years. The inability to satisfy the domestic and, to a large extent, industrial needs for electricity is reported to have had debilitating impact on the growth potentials of the Nigerian economy (World Bank, 1991). Even so, the demand for electricity, according to NEPA, is projected to increase from 5,746 megawatts in 2005 to nearly 297,900 megawatts by the end of 2030. This implies that NEPA needs to add approximately 11,686 megawatts of electricity to its stock each year in order to match this projection.

Electricity consumption per capita has been rising over the years, except for a few dips (i.e. in 1981, 1984, 2001, 2006, and 2009). Since 1971, electricity consumption per capita increase from 28.49 kWh/person to 153.93 kWh/person in 2012 (see Figure 1). Economic growth, on the other hand, has followed an irregular pattern alternating between negative and positive figures until 2003. From a growth rate of 7.5% in 2003, increasing electricity consumption per capita have been followed by stable economic growth around 3%. The rate of inflation did not have any clear-cut relationship with electricity consumption per capita, and economic growth as Figure 1 shows.

Figure 1: Electricity Consumption, Inflation, and Economic Growth Trends (1971—2012)



Source: Constructed by author from the WDI, 2014.

3. Literature Review

The electricity-growth causality debate has taken twists and turns in the literature without a common conclusion. The classic debate was whether energy consumption causes economic growth or economic growth causes energy consumption. The fact that electricity consumption forms a higher percentage of energy consumption in most countries has shifted the original debate to what our paper examines. Four major strands of conclusions on the electricity-growth causality debate are now established in the literature.

The first strand concludes that electricity consumption causes economic growth (electricity-led growth thesis); the second strand concludes that economic growth causes electricity consumption (the growth-driven electricity consumption thesis). The third strand concludes that there is bidirectional causality between electricity consumption and economic growth (the feedback thesis); finally, the fourth strand argues that there is no causal link between electricity consumption and economic growth (the neutrality thesis).

The electricity-led economic growth thesis has since been confirmed by studies, such as those of Masih and Masih (1996) for India; Asafu-Adjaye (2000) for India and Indonesia; Wolde-Rufael (2004) for Shanghai; Lee (2005) for 18 developing countries; Ho and Siu (2007) for Hong Kong; and Narayan and Singh (2007) for Fiji.

In addition, the growth-driven electricity consumption thesis has been confirmed by studies, such as those of Kraft and Kraft (1978) for the USA; Yu and Choi (1985) for the Philippines; and more recently, by Al-Iriani (2006) for the Gulf Co-operation Countries and Wolde-Rufael (2006) for the case of Cameroon, Ghana, Nigeria, Senegal, Zambia and Zimbabwe.

However, the feedback causality between electricity consumption and economic growth has been identified by Masih and Masih (1996) for Pakistan; Glasure and Lee (1997) for South Korea and Singapore; Asafu-Adjaye (2000) for Thailand and the Philippines; Soytas and Sari (2003) for Argentina; Fatai et al. (2004) for Thailand, and the Philippines; Oh and Lee (2004) for South Korea; and Odhiambo (2009) for the case of South Africa.

There are, interestingly, studies that found no causal link between electricity consumption and economic growth. Some of those studies are Erol and Chu (1987), and Yu and Jin (1992) for the case of the USA; Murray and Nan (1996) for France; Germany, India, Israel, Luxembourg, Norway, Portugal, UK, USA and Zambia; Soytas and Satri (2003) for Canada, Indonesia, Poland, USA and UK; and Akinlo (2008) for Cameroon, Cote d'Ivoire, Kenya, Nigeria, and Togo. We present some of the empirical studies on the electricity-growth causality debate in Table 1 below.

Table 1: Selected Studies on the Electricity Consumption (Energy)-Growth Debate

Author(s)	Countries	Methodology	Variables	Conclusion(s)
Kraft and Kraft (1978)	USA(1947—1974)	Bivariate Sims Causality Test	Energy Consumption; Real GDP	Y→EC
Yang (2000)	Taiwan (1954—1997)	Engle-Granger; No Cointegration; VAR	Electricity Consumption; Real GDP	ELC↔Y
Narayan and Smyth (2005)	Australia (1966—1999)	ARDL Bound Test; Cointegration; VEC Zivot-Andrews Structural Break Test; Hansen and Brown Parameter Stability Tests	Electricity Consumption per capita; Real GDP per capita; Manufacturing Employment Index	Y→EC ME→ELC
Glasure and Lee (1997)	South Korea & Singapore (1961—1990)	Bivariate VECM	Energy Consumption; Real GDP	EC↔Y
Fatai et al (2004)	Indonesia, India, Thailand and Philippines (1960—1999)	Bivariate Toda and Yamamoto (1995)	Energy Consumption; Real GDP	EC→Y Indonesia & India EC↔Y Thailand & Philippines
Wolde-Rufael (2004)	Shanghai (1952—1999)	Bivariate Toda and Yamamoto (1995)	Electricity Consumption; Real GDP	ELC→Y
Murray and Nan (1996)	Germany, Israel, Portugal, USA, UK, Zambia, France and Norway (1970—1990)	Granger Causality; VAR	Electricity Consumption; Real GDP	ELC~Y
Akinlo (2008)	Nigeria (1980—2006)	Johansen-Juselius; Cointegration; VEC; Co-feature Analysis	Electricity Consumption; Real GDP	ELC→Y
Odhiambo (2009)	South Africa and Tanzania (1971—2006)	ARDL Bounds Test; Cointegration; Johansen-Juselius; VEC	Electricity Consumption; Real GDP per capita; Employment (for South Africa)	Y→ELC Tanzania ELC↔Y South Africa

Note: →,↔, and~ denote unidirectional causality, bidirectional causality, and no causality, respectively. EC, ELC, ME and Y represent energy consumption, electricity consumption, manufacturing employment and income (GDP) respectively.

Source: Compiled by author from various studies

4. Methodology

4.1 Johansen Procedure for Investigating the Existence of Cointegration

In this paper, we adopt the Johansen procedure proposed by Johansen (1988), Johansen and Juselius (1990), and Johansen (1991 and 1995) to examine the existence of cointegration. The Johansen procedure is based on the following specifications:

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + Bx_t + \varepsilon_t \qquad (1)$$

Where y_t is a k-vector non-stationary I(1) variables (i.e. electricity consumption per capita, inflation rate, and real GDP per capita, in the our paper); x_t is a d-vector of deterministic variables; and ε_t is a vector of innovations or disturbances. Equation (1) could be formulated in the form:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-1} + Bx_t + \varepsilon_t \qquad (2)$$

Where: $\Pi = \sum_{i=1}^{p} A_i - I$ and $\Gamma_i = \sum_{j=i+1}^{p} A_i$

According to the Granger representation theorem, if the coefficient matrix, Π, has a reduced rank, $r < k$, then there exist $k \times r$ matrices α and β each with rank r such that $\Pi = \alpha\beta'$ and $\beta' y_t$ is stationary. Where r denotes the number of cointegration relations and β denotes the cointegrating vector; α represents the adjustment parameters in vector error-correction model. The Johansen Procedure estimates the matrix Π from an unrestricted vector autoregressive model and test whether the restrictions implied by the reduced rank of Π could be rejected (see Johansen, 1995).

Johansen and Juselius (1990), Johansen (1995) developed the Trace test (λ_{trace}) and Maximum eigenvalue test (λ_{max}) for doing this. Gonzalo and Pitarakis (1998), and Aznar and Salvador (2002) suggested that we could instead determine the number of cointegration relations by defining an estimator which minimises an information criterion with known asymptotic properties. In this paper, we select the number of cointegrating relations that minimises the Schwarz Bayesian information criterion (SBIC) or the Hannan-Quinn information criterion (HQIC).

4.2 Specification for Granger Causality Test

The paper employs a residual-based Granger causality test to establish the direction of the causal link between electricity consumption and economic growth in Nigeria. This approach is preferred because we are able to separate short-run causality from long-run causality (see Odhiambo, 2008). The residual-based causality test is performed in a trivariate vector error-correction framework in order to avoid variable-omission bias that featured previous studies. The choice of inflation as intervening variable was motivated by the theoretical links between inflation, electricity consumption, and economic growth. Following Mulligan (2005), we formulate a trivariate vector error-correction model of the form:

$$\Delta lnGDP_t = \gamma_0 + \sum_{i=1}^{m} \gamma_{1i} \Delta lnGDP_{t-i} + \sum_{i=1}^{n} \gamma_{2i} \Delta lnELC_{t-i} + \sum_{i=1}^{n} \gamma_{3i} \Delta lnINF_{t-i} + \gamma_4 ECM_{t-1} + u_t \tag{3}$$

$$\Delta lnELC_t = \Theta_0 + \sum_{i=1}^{m} \Theta_{1i} \Delta lnGDP_{t-i} + \sum_{i=1}^{n} \Theta_{2i} \Delta lnELC_{t-i} + \sum_{i=1}^{n} \Theta_{3i} \Delta lnINF_{t-i} + \Theta_4 ECM_{t-1} + \omega_t \tag{4}$$

$$\Delta lnINF_t = \psi_0 + \sum_{i=1}^{m} \psi_{1i} \Delta lnGDP_{t-i} + \sum_{i=1}^{n} \psi_{2i} \Delta lnELC_{t-i} + \sum_{i=1}^{n} \psi_{3i} \Delta lnINF_{t-i} + \psi_4 ECM_{t-1} + \varepsilon_t \tag{5}$$

Where $lnGDP$, $lnELC$, and $lnINF$ are, respectively, the natural logarithms of real GDP per capita, electricity consumption per capita, and inflation rate. γ,Θ, and ψ are the parameters of the model; ECM_{t-1} is the one-period lagged of the error correction term; u, ω, and ε are the innovations.

We establish the direction of long-run causality between the variables by conducting a test of significance (a *t*-test) on the lagged error-correction term in each equation. The direction of short-run causal relationships between the variables can also be established by conducting a joint test of statistical significance (an *F*-test) of the explanatory variables in each of the equations (see Oh and Lee, 2004; Narayan and Smyth, 2005; and Odhiambo, 2009).

The paper employs annual time series covering the period 1971—2012. The data were limited, because records on energy consumption in Nigeria were not available before 1971. The data on economic growth, energy consumption, and inflation rate were extracted from the World Development Indicators (2014), compiled by the World Bank. Real GDP per capita (constant 2000 US$) was used to proxy economic growth; electricity power consumption (kWh per capita) was used to proxy electricity consumption; and change in consumer price index (annual percentage change) was used to proxy inflation.

4.3 Analysis of Variables and Estimations

4.3.1 Tests for Unit Roots

The natural step towards examining the causal links between electricity consumption, inflation, and real GDP per capita in the vector error-correction framework is to first investigate the stationary[3] properties of these variables. We can only make standard inferences when the variables in the model are not integrated (or are stationary). Unit-root tests were designed to investigate the stationary properties of the time-series observations.

This paper employs the Phillips-Perron (PP) test due to Phillips and Perron (1988), and the Dickey-Fuller Generalised Least Squares (DF-GLS) test due to Elliot *et al.* (1996) to examine

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[3] A variable is said to be stationary or has no unit root when its moments do not depend on time (See Enders, 2004).

the unit root properties of the variables. These two tests were chosen, because they are able to control for serial correlation when testing for unit roots. The test for unit roots of the variables in levels, not provided here, indicated that the null hypothesis of unit roots could not be rejected. However, the first difference of variables, presented in Table 2, were found to be stationary.

Table 2: PP and DF-GLS Test for Unit Roots in First Difference

	Phillips-Perron		DF-GLS	
Variable	No Trend	Trend	No Trend	Trend
$\Delta lnGDP$	-5.662***	-6.120***	-3.291***	-3.756 ***
$\Delta lnELC$	-8.927 ***	-9.004***	-2.660***	-6.300***
$\Delta lnINF$	-3.256**	-3.238*	-2.869***	-3.168*

Note: 1) Truncation lag for DF-GLS is based on the Schwert criterion
2) Truncation lag for Phillips-Perron is based on the Newey-West bandwidth
3) *, ** and *** denote significance at 10%, 5% and 1% levels, respectively

4.3.2 Results of Johansen Tests for Cointegration

Since the variables were found to be I(1) processes, it was likely that they would move together in the long run when they drift apart in the short run. We employed the Johansen procedure to examine the potential long-run relationships between these variables. To do this, we first determined the optimal lags to be used in equation (2). From the various information criteria, the Likelihood Ratio (LR), Akaike information criterion (AIC), and Hannan-Quin information criterion (HQIC) selected an optimal lag of 4. Using the optimal lag of 4, we performed the Trace, Maximum eigenvalue, and Minimise information criterion tests on equation (2) and reported the results in Table 3.

The evidence of cointegration relationship between electricity consumption, inflation, and economic growth was confirmed by the Trace, Maximum eigenvalue, and Minimise information criterion tests at 5%, and 1% levels of significance. All three tests failed to reject a maximum of one cointegration relationship (see Tables 3a, 3b, and 3c). To verify which variable forms the cointegrating vector, we estimated the vector error-correction model. The results of the vector error-correction model (not shown) indicate that real GDP per capita is the cointegrating vector.

Table 3: Johansen Tests for Cointegration

(a) Trace Statistic

Maximum rank	Parms	LL	Eigenvalue	Trace statistic	5%	1%
0	30	135.95		36.3956	29.68	35.65
1	35	149.18	0.50172	9.9250*	15.41	20.04
2	38	152.29	0.15103	3.7033	3.76	6.65
3	39	154.14	0.09286			

(b) Maximum Eigenvalue Statistic

Maximum rank	Parms	LL	Eigenvalue	Maximum statistic	5%	1%
0	30	135.95		26.4706	20.97	25.52
1	35	149.18	0.50172	6.2217*	14.07	18.63
2	38	152.29	0.15103	3.7033	3.76	6.65
3	39	154.14	0.09286			

(c) Minimizing an Information Criterion

Maximum rank	Parms	LL	Eigenvalue	SBIC	HQIC	AIC
0	30	135.95	-4.2833	-5.11616	-5.57614	
1	35	149.18	0.50172	-4.50127*	-5.4729*	-6.0096
2	38	152.29	0.15103	-4.37782	-5.43277	-6.0154
3	39	154.14	0.09286	-4.37955	-5.46226	-6.0602

Note: * implies at maximum cointegration equations in vector error-correction model.

4.3.3 Results of the Granger Causality Test

Once electricity consumption, inflation, and economic growth were found to be cointegrated, it was clear that there is causal flow in at least one direction. Ultimately, we proceeded to verify the directions of causal flow. Nonetheless, consistent estimates and policy forecasting could only be realised when the underlying vector error-correction model specified satisfies the assumptions featuring its building blocks. Consequently, we performed various diagnostic tests before carrying out the causality test.

The Lagrange-multiplier test failed to reject the null hypothesis of no autocorrelation up to the maximum lag of four. Hence, the model was free of autocorrelation problems. Besides, the Jarque-Bera test failed to reject the null hypothesis that the disturbance terms in the model were drawn from a normal distribution; thus, the disturbance terms in our model are normally distributed. Finally, the modulus of the eigenvalues computed for the model parameters were considerably not closer to unity; thus, the estimated vector error-correction model was stable.[4]

Having verified that the vector error-correction model estimated was free from errors, we performed the residual-based Granger causality test in two steps. In step one, we test how the lagged differenced explanatory variables affect the dependent variable, in order to establish the short-run causality, using the restricted *F*-test (or the Wald test). In step two, we test for the significance of the lagged error-correction terms, ECM_{t-1}, in order to establish long-run causality between the explanatory variables and the dependent variable, using the *t*-test. Our results for the causality test are reported in Table 4.

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[4] Find the results of the diagnostic tests in the Appendix

Table 4: Causal links between Electricity Consumption, Inflation, and Economic Growth

	W-statistics [P-value]			Coefficient [t-statistics]
	$\Delta lnGDP$	$\Delta lnELC$	$\Delta lnINF$	ECM_{t-1}
$\Delta \boldsymbol{lnGDP}$	-----	5.13[.000]	3.34[.019]	-.136[-3.53]***
$\Delta \boldsymbol{lnELC}$	0.87[0.599]	-----	5.53[.000]	.234[1.89]*
$\Delta \boldsymbol{lnINF}$	2.52[.028]	1.15[0.452]	-----	-.052[-0.51]

Note: * and ** imply statistical significance at 10% and 1% levels, respectively.

The results (see Table 4) indicate a distinct causal flow from electricity consumption to economic growth both in the short run and in the long run. The short-run causal flow from electricity consumption to economic growth was supported by the *p-value* of 0.000 resulting from the joint statistical test of significance of the lags of $\Delta lnELC$ in Equation (3). And the long-run causal flow from electricity consumption to economic growth was supported by the statistical significance and negativity of the lag error correction term in Equation (3). Our results, thus, support the electricity-led growth evidence extensively documented in the literature (see Masih and Masih, 1996; Asafu-Adjaye, 2000; Wolde-Rufael, 2004; Lee, 2005; Narayan and Singh, 2007; and Akinlo, 2008).

In addition, there exists bidirectional causality between inflation and economic growth in the short run. This was supported by the *p-values* of 0.019, and 0.028 associated with the joint statistical test of significance of lags of $\Delta lnINF$ in Equation (3), and lags $\Delta lnGDP$ in Equation (5), respectively. Besides, inflation was found to Granger-cause electricity consumption in the short run (see Table 4). Finally, there was a distinct causal flow from inflation to economic growth in the long run.

5. Conclusion

The paper examined the linkages between electricity consumption and economic growth in Nigeria within a trivariate VECM. The paper was motivated by the dearth in empirical studies on the electricity-growth causality debate in Nigeria. Apart from this, the few studies available are constrained in two ways, rendering their findings sceptical: a) Omission-of-variable bias, when testing for causality within a bivariate model; and b) over-reliance on cross-sectional data to explain country-specific issues. These limitations are resolved in our paper. The paper found electricity consumption, inflation, and economic growth to be cointegrated; economic growth was found to be the cointegration vector using the Johansen procedure for testing cointegration. The paper found a distinct causal flow from electricity consumption to economic growth both in the short-and long-run. In addition, the paper found bidirectional causality between inflation and economic growth in the short run; inflation was found to Granger-cause electricity consumption in the short run; and there was a distinct causal flow from inflation to economic growth in the long run. The paper recommends that policymakers implement policies that enhance electricity generation in Nigeria. Moderate conservation policies should also be implemented in order to preserve electricity for the future. Monetary policies must also be pursued rigorously to moderate the rise in inflation which has dampening effect on economic growth.

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APPENDIX

Diagnostic Tests

Table 5 (a): Lagrange-Multiplier Test for Autocorrelation

Lag	Chi-square	Degrees of Freedom	Prob>Chi-square
1	11.239	9	0.25611
2	7.2384	9	0.61231
3	8.8198	9	0.45408
4	6.0150	9	0.73841

Null Hypothesis: No Autocorrelation at Lag Order

Table (b): Jarque-Bera Test for Normality

Equation	Chi-square	Degrees of Freedom	Prob>Chi-square
$\Delta lnGDP$	1.233	2	0.53996
$\Delta lnELC$	1.134	2	0.56735
$\Delta lnINF$	2.142	2	0.34258
All	4.506	6	0.60820

Null Hypothesis: Error Terms are drawn from a Normal Distribution

Table (c): Eigenvalue Stability Condition

Eigenvalue	Modulus
1	1
1	1
0.8620134+0.20568i	0.886212
0.8620134-0.20568i	0.886212
-0.5076486+0.7134147i	0.875596
-0.5076486-0.7134147i	0.875596
0.02335967+0.7152056i	0.715587
0.02335967-0.7152056i	0.715587
.5340696 + .2065688i	0.572626
0.5340696-0.2065688i	0.572626
-0.289026+0.4037361i	0.496527
-0.289026-0.4037361i	0.496527

Note: The VECM specification imposes 2 unit moduli.

Figure 2: Graph for Eigenvalue Stability Condition