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Electricity Consumption and Economic Growth in West Africa: A Test of the Feedback Thesis

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Abstract
Background: *In this paper, the influence of electricity consumption on economic growth was examined for the period 1971 to 2014. The study focuses on seven (7) West African countries of Benin Republic, Cote d'Ivoire, Cameron, Ghana, Nigeria, Senegal, and Togo. The choice of the time frame and countries were premised upon data availability.*
Materials and Methods: *The study utilized data from the World Development Indicators. Data were analysed using unit root test approach of Im, Pesaran and Shin along with the Augmented Dickey-Fuller-Fisher approach for individual unit root test; while Levine, Lin and Chu as well Breitung approaches were utilized in examining common unit root test. Further, the study utilized the Dumitrescu-Hurlin panel causality test approach to examine the nature of the relationship between electricity consumption per capita and gross domestic product per capita. Also, the study employed the error correction mechanism (ECM) to examine the long run and short run dynamics of the model; along with the vector autoregressive (VAR) technique to obtain the VAR estimates so as to obtain the variance decomposition and the impulse response function.*
Findings: *From the unit root test, all the variables were stationary at first difference which prompted the test for cointegration. The cointegration result, through the use of the residual test, shows that the variables were cointegrated. From here, we estimated both the short run and long run estimates of the functions. In respect to gross domestic product per capita, it was observed that electricity consumption per capita exerted a positive and significant effect on gross domestic product per capita both in the short run and in the long run. The error correction mechanism indicated that 6.89% of the short run errors in gross domestic product per capita is corrected annually. In terms of electricity consumption per capita, it was discovered that gross domestic product per capita have a positive and significant long run effect on electricity consumption per capita. Meanwhile, gross domestic product per capita exerted a positive but insignificant effect on electricity consumption per capita in the short run. The error correction mechanism indicated that 12.24% of the short run errors is corrected annually. The VAR results shows that both electricity consumption per capita and gross domestic product per capita have a strong endogenous impact; while electricity consumption is weakly exogenous but gross domestic product per capita is strongly exogenous. The feedback thesis on electricity consumption and economic growth was validated since the causality test revealed a bidirectional causality between the two variables.*
Conclusion: *Electricity is a major input in the production function. There is need for policies that will boost electricity generation, transmission and distribution in the West African sub-region. The adoption and development of alternative energy sources such as solar power needs to be intensified so as to augment the epileptic power supply and attendant high bills; while concerted efforts towards conservation of electricity for the future should be effectively implemented.*
Keywords: *Electricity Consumption, Economic Growth, Variance Decomposition, Impulse Response Function, Electricity-led Growth Thesis, Growth-Driven Electricity Consumption Thesis, Feedback Thesis.*
JEL Classification: *C23, Q43*

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I. Introduction

The direction of association between energy consumption and economic growth have been considered in four major perspectives. First, advocates of the electricity-led growth thesis are of the view that electricity consumption causes economic growth. Thus, the idea here is that electricity is a key driver of growth in any modern economy. This strand of thought received empirical considerations from several works [1 – 6], who have all confirmed that consumption of electricity causes economic growth. The electricity-led growth thesis therefore implies that a unidirectional causality flows from electricity consumption to economic growth.

The growth-driven electricity consumption thesis is the second strand of conclusion in the literature. Here, economic growth is believed to cause electricity consumption. Thus, higher economic growth will stimulate the demand for greater amount of electricity since more kilowatts of electricity will be consumed as more economic activities ensues. This strand has also received empirical testing from several studies [7 – 10]. Their findings confirmed the validity of the growth-driven electricity consumption thesis. Here, a unidirectional causality flows from economic growth to electricity consumption.

The third school of thought hinges on the feedback thesis. Here, a bidirectional causality is believed to exists between the use of electricity and economic growth. It follows that the two variables cause each other, implying that electricity consumption causes economic growth; and economic growth in turns causes electricity consumption [11 – 15]. All these studies identified the existence of the feedback thesis. The final strand is of the opinion that there is no relationship between the use of electricity and economic growth. This has been regarded as the neutrality thesis. This thesis has been validated through the findings of some studies [16 – 19]. Thus, the neutrality thesis concludes that electricity consumption does not cause economic growth; and economic growth do not in any way cause electricity consumption.

These series of studies have therefore proven the idea that electricity is crucial for the stimulation of economic growth of nations in general and West Africa in particular. Electricity is an important input in the production process and thus, its efficiency in supply is likely to boost production of goods and services. Also, the cost of self-generation of powers by business entities can be drastically reduced; making entrepreneurs to save cost. Thus, stable electricity supply will boost efficiency and productivity as well as encouraging investors and entrepreneurial activities [20].

Within the Sub-Saharan Africa, electricity consumption per capita over the years have witnessed insignificant improvements. The value of electricity consumption per capita as at 1971 was 320.78kw/h but steadily rose to 470.88kw/h as at 1980. Between 1981 to 1990, electricity consumption per capita averaged 516.41kw/h but only rose to an average of 519.37kw/h between 1990 to 2000. Meanwhile, the average electricity consumption per capita between 2001 to 2014 has declined to only 508.44kw/h. The trend is depicted in Figure 1.

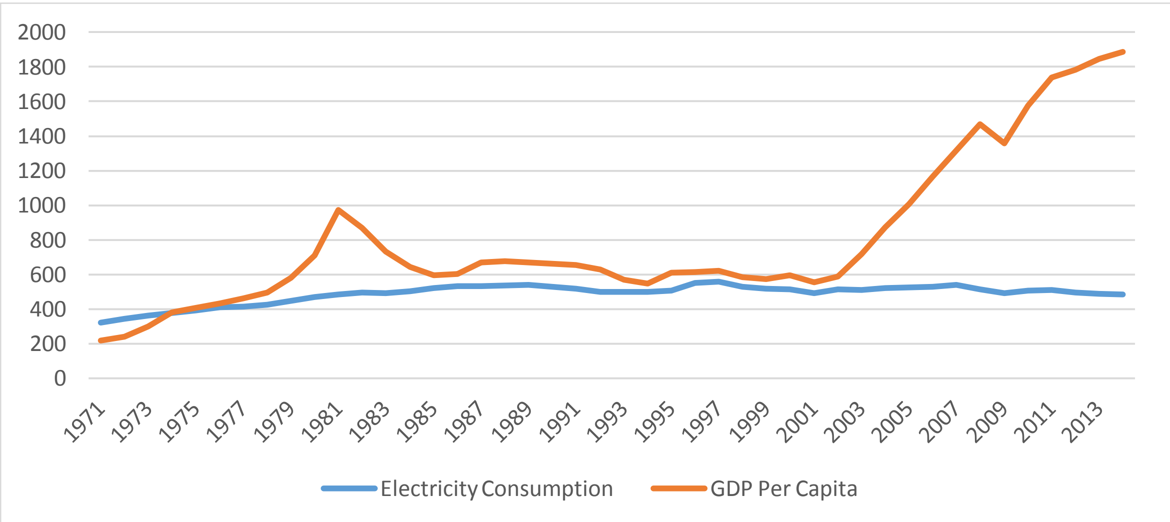

Figure 1: Trend of Electricity consumption and GDP Per Capita for Sub-Saharan Africa

This paper therefore seeks to examine the feedback thesis so as to ascertain the nature of association existing between the use of electricity and economic growth. In particular, the paper seeks to achieve the following objectives:

i. To ascertain the nature of the association existing between electricity consumption per capita and the per capita gross domestic product;
ii. To investigate the effect of electricity consumption per capita on gross domestic product per capita;
iii. To examine the effect of gross domestic product per capita on electricity consumption per capita;
iv. To investigate the existence of a long run relationship between electricity consumption per capita and per capita gross domestic product; and
v. To reveal how gross domestic per capita responds to shocks in electricity consumption per capita and vice versa.

The setup of this paper is in a five-section structure where this introductory section is followed by the literature review in Section II. Adumbrated in Section III is the methodology of the research while Section IV presents the empirical findings and discussion. Finally, Section V captures the conclusion aspect of the paper.

II. Literature Review

Empirical evidence on the linkages between electricity consumption and economic growth is presented below.

Author(s)	Variables	Methodology	Country and Period	Findings
Glasure and Lee [11]	Energy consumption and Real GDP	Bivariate VECM	South Korea and Singapore (1961 – 1990)	A bidirectional between energy consumption and real GDP.
Narayan and Smyth [21]	GDP per capita, energy consumption per capita, and gross fixed capital per capita.	Panel Cointegration, and Panel Causality	G7 Countries (1972 – 2002)	All the variables are cointegrated. Gross fixed capital formation and energy consumption causes positive real GDP growth in the long run.
Narayan and Smyth [22]	Electricity Consumption per capita Real GDP per capita Manufacturing employment Index	ARDL Bound Test Cointegration VEC	Australia (1966 – 1999)	Unidirectional causality from real GDP per capita to electricity consumption per capita. A unidirectional causality from manufacturing employment index to electricity consumption per capita.
Okorie and Manu [23]	Real Gross Domestic Product, Electricity consumption, Capital formation, and Labour Force	Cointegration VAR	Nigeria (1980 – 2014.	Unidirectional causality between the use of electricity and economic growth. A long run relationship exist between the use of electricity and economic growth.
Ghosh [24]	GDP Per capita and electricity consumption per capita.	Engel-Granger approach Standard Granger causality	India (1950 – 1997)	Absence of cointegration. Unidirectional causality from electricity consumption per capita to GDP growth per capita.
Yang [25]	Electricity consumption and Real GDP	Engle-Granger Cointegration VAR	Taiwan (1954 – 1997)	No cointegration. A bidirectional causality between the use of electricity and economic growth.
Wolde-Rufael [3]	Electricity Consumption and Real GDP	Bivariate Toda and Yamamoto (1995)	Shanghai (1952 – 1999)	A unidirectional causality from electricity consumption to real GDP.
Odhiambo [15]	Electricity Consumption, Real GDP per capita, and Employment	ARDL Bounds Test Cointegration VEC	South Africa and Tanzania (1971 – 2006)	Unidirectional causality flowing from Real GDP per capita to Electricity consumption in Tanzania. Bidirectional causality between electricity consumption and real GDP per capita in South Africa.
Javid, Javid and Awan [26]	Electricity consumption per capita and gross domestic product per capita.	Engel and Granger cointegration test. Structural Vector Autoregression (SVAR)	Pakistan (1971 – 2008)	Long run relationship between real GDP per capita and electricity consumption. Unidirectional causality running from electricity consumption to economic growth.
Bernard [27]	Real GDP per capita, Electricity consumption per capita, and Inflation rate	Trivariate VECM	Nigeria (1971 – 2012)	A distinct causal flow from electricity consumption to economic growth both in the short run and in the long run.
Ismail, Rashid, and Hanif [28]	Real GDP, Electricity consumption, Total labour force, and Gross fixed capital formation	Granger causality VAR	ASEAN (1983 – 2012)	No causality in the short run. Bidirectional relationship among variables in the long run.
Ogundipe [29]	Real GDP, Electricity consumption, labour force, and gross fixed capital formation.	Granger Causality Cointegration VECM	Nigeria (1980 – 2008)	Existence of a unique co-integrating relationship among the variables in the model with the indicator of electricity consumption impacting significantly on growth. Bidirectional causal relationship between the use of electricity and economic growth.

Faisal, Tursoya, Resatoglua and Berk [20]	Electric power consumption per capita, Real GDP per capita, trade openness, and urbanisation.	ARDL bounds testing approach to co-integration Granger Causality VECM	Iceland (1965–2013)	Long run relationship between electricity consumption and its regressor; with attendant positive and significant impact of economic growth, trade and urbanisation on electricity consumption. Feedback causal relationship between urbanisation and electricity consumption in the long-run. No causal relationship between electricity usage and economic growth.
Soytas and Sari [12]	Electricity consumption, and economic growth.	Vector error correction model Granger Causality test	Italy, Japan, South Korea (1950 – 1992)	No causality between the use of electricity and economic growth.
Raza, Jawaid, and Siddiqui [30]	Real gross domestic product, Labour, Capital and Electricity consumption.	Pedroni's panel cointegration Panel Granger causality test Random effect model	South Asian countries - Pakistan, India, Bangladesh and Sri Lanka (1980 – 2010)	Existence of long run relationship between electricity consumption and economic growth in South Asia. Positive and significant impact of electricity consumption on economic growth of South Asian countries. Unidirectional causal relationship running from electricity consumption to economic growth.
Fatai, Oxley, and Scrimgeour [13]	Energy Consumption and Real GDP	Bivariate Toda and Yamamoto (1995)	Indonesia, India, Thailand and Philippines (1960 – 1999)	A unidirectional causality flowing from energy consumption to real GDP in Indonesia. A bidirectional causality flowing between energy consumption and real GDP in Thailand and Philippines.
Kasperowicz [31]	Real GDP, Electricity consumption, Total employment, and Gross fixed capital	Granger causality Multiple regression.	Poland (2000 – 2012)	Bidirectional causal relationship between the use of electricity and economic growth. Electricity consumption is a pro-growth variable.
Twerefou*et al.* [32]	Electricity consumption, Real GDP	Vector Error Correction Model, Granger causality	Ghana (1975–2006)	A unidirectional causality flows from GDP to electricity consumption.
Akinlo [19]	Real GDP and Electricity consumption.	Fully modified ordinary least square (FMOLS)	Ghana, Gambia and Senegal (1980 – 2003)	A bidirectional causality between electricity consumption and real GDP.

Source: Review of related literature from various journal articles.

The empirical literature review presented above indicates mixed findings on the relationship between the use of electricity and economic growth. These variations can be attributed to factors such as the country involved, the period that the study covers, and the technique of analysis. This paper will therefore focus on electricity consumption per capita and gross domestic product per capita within the confines of the West Africa sub-region.

III. Methodology

Model Specification

In examining the relationship between electricity consumption and economic growth, some studies utilized a multivariate approach [14, 15, 22]. However, other studies employed the bivariate models [3, 11, 12, 18, 19, 24 – 26, 33]. This study also align itself with the bivariate vector autoregressive (VAR) model to examine the relationship between electricity consumption and economic growth within the West African region. In specifying the models for this study, we carry out the process by basing each model on the objective that is to be achieved.

To examine the effect of electricity consumption per capita on gross domestic product per capita in West Africa, the study adopts the model of Javid *et al.* [26] who examined electricity consumption and economic growth in Pakistan. The model is specified as follows:

$$logGDPPC_{it} = \alpha_0 + \alpha_1 logELECT_{it} + \mu_{1t} \qquad (1)$$

Similarly, to examine the effect of gross domestic product per capita on electricity consumption per capita in West Africa, the model is built based on Javid *et al.* [26] study. It is specified below.

$$logELECT_{it} = \beta_0 + \beta_1 logGDPPC_{it} + \mu_{2t} \qquad (2)$$

Where GDPPC is the gross domestic product per capita, ELECT is electricity consumption per capita, log is the natural log , α_0, α_1, β_0, and $\beta_1$are the parameters to be estimated, i denotes the country and t is the time.
To examine the nature of the association between electricity consumption per capita and gross domestic product per capita, the model for the causality test is specified as follows:

$$\begin{cases} logGDPPC_{it} = \emptyset_i + \sum_{k=1}^{k} \pi_{ik} logGDPPC_{i,t-k} + \sum_{k=1}^{k} \vartheta_{ik} logELECT_{i,t-k} + \varepsilon_{1t} \\ logELECT_{it} = \emptyset_i + \sum_{k=1}^{k} \pi_{ik} logELECT_{i,t-k} + \sum_{k=1}^{k} \vartheta_{ik} logGDPPC_{i,t-k} + \varepsilon_{2t} \end{cases} ------------ (3)$$

The null hypothesis for the causality test is specified thus;
$\begin{cases} H_0: \pi_{1k} = \pi_{2k} = \cdots = \pi_{ik} = 0 \\ H_0: \vartheta_{1k} = \vartheta_{2k} = \cdots = \vartheta_{ik} = 0 \end{cases}$ which in fact states the absence of causality.

Sources of Data

Data for this study covers the period 1971 to 2014 which covers the period of 43 years. The seven (7) West African countries selected based on data availability include Benin Republic, Cote d'Ivoire, Cameron, Ghana, Nigeria, Senegal, and Togo. Data were obtained from the World Development Indicators [34] extracted from the World Bank database. The variables include gross domestic product per capita and the electricity consumption per capita.

Estimation Technique

The techniques utilized in the analysis of the data include the panel unit root test, panel causality test, vector error correction, and vector autoregression.

Panel Unit Root Test

The panel unit root test employed in this paper is the one developed by Im, Pesaran and Shin [35] and the ADF-Fisher approaches. Meanwhile, the common unit root process is based on Levine, Lin and Chu [36] and Breitung unit root test approach. The model of the unit root test is specified as follows:

$$\begin{cases} \Delta logGDPPC_{it} = \gamma_{1i} + \beta_{1i} logGDPPC_{i,t-1} + \sum_{j=1}^{k} \pi_{ij} \Delta logGDPPC_{i,t-j} + \delta t_1 + \mu_{1t} \\ \Delta logELECT_{it} = \gamma_{2i} + \beta_{2i} logELECT_{i,t-1} + \sum_{j=1}^{k} \pi_{ij} \Delta logELECT_{i,t-j} + \delta t_2 + \mu_{2t} \end{cases} -------- (4)$$

Where Δ is the difference operator. The null hypotheses are that there is a unit root which is specified as follows:
$\begin{cases} H_0: \beta_{1i} = 1 \\ H_0: \beta_{2i} = 1 \end{cases}$ against the alternative hypothesis that $\begin{cases} H_1: \beta_{1i} < 1 \\ H_1: \beta_{2i} < 1 \end{cases}$ which states that the variables are stationary.

Panel Granger Causality Test

The Dumitrescu-Hurlin heterogeneous panel causality test developed by Dumitrescu and Hurlin [37]is utilized in examining the nature of the relationship between the variables of interest under a panel data framework. This framework provides the means through which we can carry out a test of causality in panel data [38]. The generalized form of the test is specified as follows:

$$y_{it} = \theta_i + \sum_{k=1}^{k} \delta_{ik} y_{i,t-k} + \sum_{k=1}^{k} \rho_{ik} x_{i,t-k} + \varepsilon_{i,t} ---------------------- (5)$$

Where y_{it} and $x_{it}$are series for country i at time t that are stationary. It is assumed that the lag order k is identical for all individuals and that the panel must be balanced.

Vector Error Correction Mechanism (ECM)

The vector error correction mechanism helps us in detecting the existence of a long run equilibrium relationship and the speed at which the short run disequilibrium is corrected so as to achieve a long run equilibrium. Through the ECM, we will be able to detect the existence or non-existence of a long relationship between electricity consumption and economic growth within the West African sub-region. This is achieved by employing the Autoregressive Distributed Lag model approach, which makes it far easier to obtain both the long run and the short run estimates. Generally, the model is specified as follows:

$$\Delta Y_{i,t} = \emptyset_{i,j} + \sum_{i=1}^{m} \varphi_{i,k} \Delta X_{i,t} + \lambda ECM_{i,t-1} + \mu_{i,t} -------------------- (6)$$

Equation (6) translates to our model in specific form as presented in Equation (7).

$$\Delta logGDPPC_{i,t} = \emptyset_{i,j} + \sum_{i=1}^{m} \varphi_{i,k} \Delta logELECT_{i,t} + \lambda ECM_{i,t-1} + \mu_{i,t} \quad ----------- (7)$$

Similarly,

$$\Delta logELECT_{i,t} = \emptyset_{i,j} + \sum_{i=1}^{m} \varphi_{i,k} \Delta logGDPPC_{i,t} + \lambda ECM_{i,t-1} + \mu_{i,t} \quad ----------- (8)$$

Where Δ denotes the first difference operator; $\emptyset_{i,j}$(j, k = 1, 2, …, N) represents the fixed country effect; i (i = 1, …, m) is lag length selected based on Schwarz Information Criterion (SIC); $X_{i,t}$ is the vector of regressors;$Y_{i,t}$ is the dependent variable; $ECM_{i,t-1}$ is the estimated lagged error correction mechanism (ECM) derived from the long-run cointegrating relationship; λ is the adjustment coefficient; and $\mu_{i,t}$ is the disturbance term,

Impulse Response Function (IRF)

The VAR model aids in detecting the endogeneity and/or exogeneity of the variables in a VAR framework. Its explanation is often backed by the variance decomposition and the impulse response function. The variance decomposition gives us an indication pertaining to the amount of information that a variable in a VAR framework contributes to the other variables in the autoregressive process. It measures the degree to which the forecast error variance of each of each of the variables can be explained by exogenous shocks to the other variables. The IRF traces the response of the endogenous variables to one deviation shock to one of the disturbance term in the system [23]. Thus, it shows the effect of shocks on the adjustment path of the variables. This shock is transmitted to all of the endogenous variables through the dynamic structure of the Vector Error Correction model [39].It is generally give as;

$$\Phi_i = \sum_{j=1}^{i} \Phi_{i-j} A_j \, , i = 1, 2, 3, \; . . . \quad ----------------------- (9)$$

Where $\Phi_0 = I_k$ and A_j = 0 for j > p;whilst K is the number of endogenous variables and p is the lag order of the VAR model.

IV. Empirical Findings And Discussion

Unit Root Test

The unit root test result on both the individual and common unit root processes is presented in Table 1. The individual unit root test follows the Im *et al.* [35] and the ADF-Fisher approaches. Meanwhile, the common unit root process is based on Levine *et al.* [36] approach as well as that of Breitung approach. The unit root test process follows the constant, and deterministic trend assumption.

Table 1: Individual and Common Unit Root Test Result

Individual Unit Root Process					Common Unit Root Process				
Im, Pesaran and Shin W-stat			ADF - Fisher Chi-square		Levin, Lin & Chu t*		Breitung t-statistics		
Variables	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference	Order of Integration
GDPPC	1.571 (0.94)	-10.46 (0.00)***	6.621 (0.95)	116.99 (0.00)***	0.319 (0.33)	-7.16 (0.00)***	6.072 (1.00)	-5.43 (0.00)***	I(1)
ELECT	-1.25 (0.11)	-12.12 (0.00)***	23.99 (0.05)*	138.34 (0.00)***	-0.44 (0.33)	-11.03 (0.00)***	-0.15 (0.44)	-8.248 (0.00)***	I(1)

*Note: * and *** denotes significance at 10% and 1% respectively. The probabilities are presented in brackets.*
Source: Output extracted from Eviews 10 software package

From Table 1, the individual unit root tests under both the Im, Pesaran and Shin approach and the ADF-Fisher approach presented that both the log of electricity consumption per capita and the log of gross domestic product per capita are stationary at first difference, I(1). Also, the common unit root test reveals that the two variables are also stationary at first difference. The stationarity of the variables at first difference warrants the test for the existence of a long run relationship which will be carried out by carrying out a unit root rest on the obtained residuals of the regression. In that way, we will be able to examine both the long run and the short run dynamics.

Granger Causality Test

The causality test follows the Dumitrescu-Hurlin panel causality test approach to examine the nature of the relationship between electricity consumption per capita and gross domestic product per capita. The result is presented in Table 2.

Table 2: Pairwise Dumitrescu-Hurlin Panel Causality Tests Result

Null Hypothesis:	W statistic	Z-bar Statistic	Probability	Decision
logELECT does not homogeneously cause logGDPPC	4.973	3.378	0.0007***	Reject
logGDPPC does not homogeneously cause logELECT	3.697	1.871	0.0614*	Reject

*Note: * and *** respectively denotes significance at 10% and 1% level*
Source: Output extracted from Eviews 10 software package

From Table 2, the pairwise causality test shows that there exist a two-way causality flowing between electricity consumption per capita and gross domestic product per capita. Thus, the log of electricity consumption homogenously causes the log of gross domestic product per capita. In the same vein, gross domestic product per capita causes electricity consumption. The implication of this findings is that high electricity consumption per capita causes high gross domestic product per capita. Also, high gross domestic product per capita causes high electricity consumption per capita because as economic activities progresses, there will be high demand for energy. It follows that the bidirectional causality upheld the feedback thesis as earlier obtained by studies like Masih and Masih [1], Glasure and Lee [11], Asafu-Adjaye [2], Soytas and Sari [12], Fatai, *et al.* [13], Oh and Lee [14], and Odhiambo [15]. This bidirectional relationship will be subject to a VAR framework to capture the response of each of the variables to a shock in one another.

Modelling Electricity Consumption and GDP Per Capita

Here, the models for the influence of electricity consumption per capita on gross domestic product per capita; and the influence of gross domestic product per capita on electricity consumption per capita are estimated. First, we start from the assumption that both gross domestic product per capita and electricity consumption per capita follows a first order autoregressive process, AR(1). The result is presented in Table 3 and Table 5.

Table 3: OLS Result for the Influence of Electricity Consumption on GDP Per Capita

Dependent Variable: Log of Gross Domestic Product Per Capita (logGDPPC)				
Variables	Coefficient	Standard Error	t-statistic	Probability
C	7.159	0.582	12.312	0.0000***
logELECT	0.046	0.018	2.547	0.0114**
AR(1)	0.993	0.007	150.506	0.0000***
R-squared = 0.9876		Adjusted R-squared = 0.9875		
F-statistic = 11894.82 (0.000)***		Durbin-Watson statistic = 1.57		

*Note: ** and *** denotes significance at the 5% and 1% level of significance respectively.*
Source: Output extracted from Eviews 10 software package

The result in Table 3 indicates that log of electricity consumption per capita has a significant positive effect on the log of gross domestic product per capita. Also, the significance of AR(1) indicates that the log of gross domestic product per capita really follows an AR(1) process. Obtaining the residuals, ε_{1t}, and testing for the stationarity will give us an idea of whether the two variables are cointegrated. If the residuals are stationary at level, then there is cointegration. This process is carried out and the result is presented in Equation (10).

$$\begin{cases} \Delta\varepsilon_{It} = -0.962\varepsilon_{1t-1} \\ \tau = -5.300 ** \end{cases} \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad (10)$$

The result of the unit root test on the residual term shows that the coefficient of ε_{1t-1} is negative and statistically significant as indicated by the tau (τ) statistic of -5.300 which is significant at the 1% level. Thus, the ε_{It} is 1(0) implying that it is stationary at levels. It follows that the stationarity of ε_{It} at levels is a clear indication that the variables are cointegrated hence, there is some degree of long run equilibrium relationship. We therefore estimate both the long run and the short run dynamics as presented in Table 4.

Table 4: Result of Error Correction Mechanism (ΔlogGDPPC)

Variables	Coefficient	Standard Error	t-statistic	Probability
Long Run Model: logGDPPC = 0.2397logELECT				
logELECT	0.2397	0.0497	4.8212	0.0000***
Short Run Model: ΔlogGDPPC = 0.3995 + 0.0826ΔlogELECT – 0.0689ECM(-1)				
ECM(-1)	-0.0689	0.0320	-2.1564	0.0319**
D(logELECT)	0.0826	0.0500	1.6510	0.0998*
C	0.3995	0.1799	2.2205	0.0272**

*Note: *, **, and *** respectively denotes significance at 10%, 5%, and 1% levels of significance.*
Source: Output extracted from Eviews 10 software package

From Table 4, shows both the long run and short run estimates. In the long run, the log of gross domestic product exerts a positive and significant effect on gross domestic product per capita. This finding validates the conclusion of the electricity-led growth thesis along with earlier studies such as Masih and Masih [1], Asafu-Adjaye [2], Wolde-Rufael [3], Lee [4], Ho and Siu [5], and Narayan and Singh [6]. Therefore, a unit percentage increase in log of electricity consumption per capita exerts a 23.97% increase in the log of gross domestic product per capita. In the short run, log of electricity consumption per capita also exerts a positive and significant effect on the log of gross domestic product per capita. Thus, a unit percentage increase in log of electricity consumption per capita will lead to an 8.26% increase in the log of gross domestic product per capita. This is an indication that electricity is a vital input in the production function. The coefficient of the error correction model (-0.0689) shows that 6.89% of the short run disequilibrium is corrected annually. However, the speed of adjustment is very slow.

We proceed to examining the influence of the log of gross domestic product per capita on the log of electricity consumption per capita. Given the assumption that the variables follows AR(1) process, the result is presented in Table 5.

Table 5: OLS Result for the Influence of GDP Per Capita on Electricity Consumption Per Capita

Dependent Variable: log of Electric power consumption in kWh per capita (logELECT)				
Variables	Coefficient	Standard Error	t-statistic	Probability
C	1.737	1.175	1.478	0.1404
LOGGDPPC	0.501	0.165	3.044	0.0025**
AR(1)	0.947	0.013	72.975	0.0000***
R-squared = 0.9535		Adjusted R-squared = 0.9532		
F-statistic = 3055.553 (0.000)***		Durbin-Watson statistic = 2.41		

*Note: ** and *** denotes significance at 5% and 1% respectively*
Source: Output extracted from Eviews 10 software package

The result in Table 5 indicates that log of gross domestic product per capita has a significant positive effect on the log of electricity consumption per capita. Also, the significance of AR(1) at 1% level of significance indicates that the log of electricity consumption per capita really follows an AR(1) process. Obtaining the residuals, ε_{2t}, and testing for the stationarity will give us an idea of whether the two variables are cointegrated. If the residuals are stationary at level, then there is cointegration. This process is carried out and the result is presented in Equation (11).

$$\begin{cases} \Delta\varepsilon_{2t} = -1.325\varepsilon_{2t-1} \\ \tau = -12.044^{***} \end{cases} \qquad (11)$$

The result of the unit root test on the residual term shows that the coefficient of ε_{2t-1} is negative and statistically significant as indicated by the tau (τ) statistic of -12.044 which is significant at the 1% level. Thus, the ε_{2t} is 1(0) implying that it is stationary at levels. It follows that the stationarity of ε_{2t} at levels is a clear indication that the variables are cointegrated hence, there is some degree of long run equilibrium relationship. We therefore estimate both the long run and the short run dynamics as presented in Table 6.

Table 6: Result of Error Correction Mechanism (ΔlogELECT)

Variables	Coefficient	Standard Error	t-statistic	Probability
Long Run Model: logELECT = 0.7131logGDPPC				
logGDPPC	0.7131	0.3533	2.0184	0.0445**
Short Run Model: ΔlogELECT = 0.0359 + 0.1022ΔlogGDPPC – 0.1224ECM(-1)				
ECM(-1)	-0.1224	0.0406	-3.0164	0.0028**
ΔlogGDPPC	0.1022	0.3156	0.3239	0.7463
C	0.0359	0.0451	0.7969	0.4262

*Note: ** denotes significance at 5% level of significance.*
Source: Output extracted from Eviews 10 software package

Table 6 presents the short and long run influence of the log of gross domestic product on the log of electricity consumption per capita. In the long run, the log of gross domestic product per capita influences the log of electricity consumption per capita positively and in in a significant way. Thus, the growth-driven electricity consumption thesis is also upheld in this case which conforms to earlier findings such as Kraft and Kraft [7], Yu and Choi [8], Al-Iriani [9],and Wolde-Rufael [10]. Thus, a unit percentage increase in the log of gross domestic product per capita exerts a 71.31% increase in the log of electricity consumption per capita. However, the log of gross domestic product per capita exerts a positive but an insignificant effect on the log of electricity consumption per capita in the short run. The coefficient of the error correction mechanism (0.1224) indicates that 12.24% of the short run disequilibrium is corrected annually.

Since our causality test indicated the existence of a bidirectional causality, we estimate the vector autoregressive (VAR) function so as to measure both the impulse response and the variance decomposition. The result is presented in Table 7.

Table 7: Vector Autoregressive Estimates

	logGDPPC			logELECT		
Variables	Coefficient	Standard Error	t-statistic	Coefficient	Standard Error	t-statistic
log(GDPPC(-1)	1.2383	0.0577	21.4701***	0.5038	0.1805	2.7917**
log(GDPPC(-2)	-0.2468	0.0576	-4.2881***	-0.4750	0.1801	-2.6375**
logELECT(-1)	-0.0049	0.0185	-0.2665	0.7564	0.0580	13.0464***
logELECT(-2)	0.0075	0.0180	0.4181	0.1894	0.0564	3.3597***
C	0.0502	0.0453	1.1101	0.0878	0.1416	0.6202
R-squared	**0.9879**			**0.9520**		
Adjusted R-squared	**0.9877**			**0.9513**		
F-statistic	**5905.111*****			**1432.844*****		

*Note: ** and *** denotes significance at 5% and 1% level of significance.*

Source: Output extracted from Eviews 10 software package

From the VAR result for logGDPPC, it is observed that log of gross domestic product per capita strongly predicts itself as indicated by the t-statistic of 21.4701 which is statistically significant. Hence, logGDPPC is strongly endogenous. Thus, the past realization of the log of gross domestic product per capita is associated with 123.83% increase in log of gross domestic product per capita on the average. Also, the two-period lag of log of gross domestic product per capita negatively and significantly influences the log of gross domestic product per capita. Thus, the two-period realization of the log of gross domestic product per capita is associated with 24.68% decrease in the log of gross domestic product per capita on the average. Meanwhile, the log of electricity consumption per capita does not significantly affect the log of gross domestic product per capita hence, it is weakly exogenous.

For logELECT, it is observed that log of electricity consumption per capita strongly predicts itself as shown by the t-statistic of 13.0464 which is significant at the 1% level. Therefore, the log of electricity consumption per capita is endogenous. It therefore implies that the past realization of the log of electricity consumption per capita is associated with 18.94% increase in the log of electricity consumption per capita. In the same vein, the two-period lag of the log of electricity consumption per capita positively and significantly influences the log of electricity consumption per capita. It therefore implies that the two-period past realization of the log of electricity consumption per capita is associated with 18.94% increase in the log of electricity consumption per capita. Also, a unit percentage increase in the log of gross domestic product per capita is associated with a 50.38% increase in the log of electricity consumption per capita. Therefore, the log of gross domestic product per capita is strongly exogenous.

To further showcase the validity of the above VAR result, the variance decomposition of the two variables of interest are presented in Table 8 and Table 9.

Table 8: Variance Decomposition of logGDPPC

Period	Standard Error	logGDPPC	logELECT
1	0.046981	100.0000	0.000000
2	0.074708	99.99072	0.009278
3	0.095997	99.99314	0.006857
4	0.113420	99.99507	0.004927
5	0.128323	99.99490	0.005096
6	0.141458	99.99225	0.007750
7	0.153271	99.98712	0.012883
8	0.164050	99.97965	0.020350
9	0.173991	99.97003	0.029969
10	0.183232	99.95846	0.041545

From Table 8 presenting the variance decomposition of the log of gross domestic product per capita, we split the analysis into short run (1 – 4) and long run (5 – 10) periods. In the short run (period 1 in particular), 100% of the forecasted error variance in log of gross domestic product per capita is explained by the variable itself. The log of electricity consumption per capita do not have any strong influence (0.000%) on log of gross domestic product per capita. That is, they have strong exogenous impact. This implies that in the short run, log of electricity consumption per capita do not influence log of gross domestic product per capita at all. This insignificant influence in observed throughout the short run period up to period 4 where the forecast error variance of log of gross domestic product per capita still explains as much as 99.995% by itself while the influence of log of electricity consumption per capita continues to decline form 0.0093% in period 2 to 0.0049% in period 4. In the long run, 99.96% of the forecast error variance in log of gross domestic product per capita is

explained by the variable itself. The log of gross domestic product per capita is still showing strong influence right from the short run into the long run period. On the log of electricity consumption per capita, the influence is rising steadily from 0.005% to 0.04% in the long run period. However, the overall influence is still very weak. Thus, log of electricity consumption is weakly exogenous. The result of the variance decomposition supports the VAR estimates where we observed a strong influence of log of gross domestic product per capita on itself while log of electricity consumption generated an insignificant effect.
We also proceed to the variance decomposition for the log of electricity consumption per capita where the result is presented in Table 9.

Table 9: Variance Decomposition of logELECT

Period	Standard Error	logGDPPC	logELECT
1	0.146987	1.735488	98.26451
2	0.187667	5.232647	94.76735
3	0.221396	6.957191	93.04281
4	0.248141	8.133877	91.86612
5	0.270552	8.976852	91.02315
6	0.289686	9.643772	90.35623
7	0.306291	10.20362	89.79638
8	0.320867	10.69488	89.30512
9	0.333775	11.13934	88.86066
10	0.345284	11.55032	88.44968

From Table 9, we observe that the log of electricity consumption explains itself strongly but such declines steadily into the future. In the first period, 98.26% of the forecast error variance in electricity consumption is explained by the variable itself but that declines to about 91.87% in the fourth period. Therefore, log of electricity consumption per capita have a strong endogenous impact. The influence of the log or gross domestic product per capita is observed to exert a steadily rising influence over the short run, with such increasing from 1.735% to 8.134% over the short run period. In the long run, the log of electricity consumption continues to explain about 88.45% of forecast error variance by itself, making it to be strongly endogenous over the long run period. However, we observed that the log of gross domestic product continues to show a rising impact from 8.98% in the fifth period to about 11.55% in the last period under consideration. Therefore, the log of gross domestic product is somewhat weakly exogenous.
Utilizing the impulse response function to capture how the variables responds to changes in each other, that is, to get a picture of the model's dynamic behaviour, the result is presented in Figure 2.

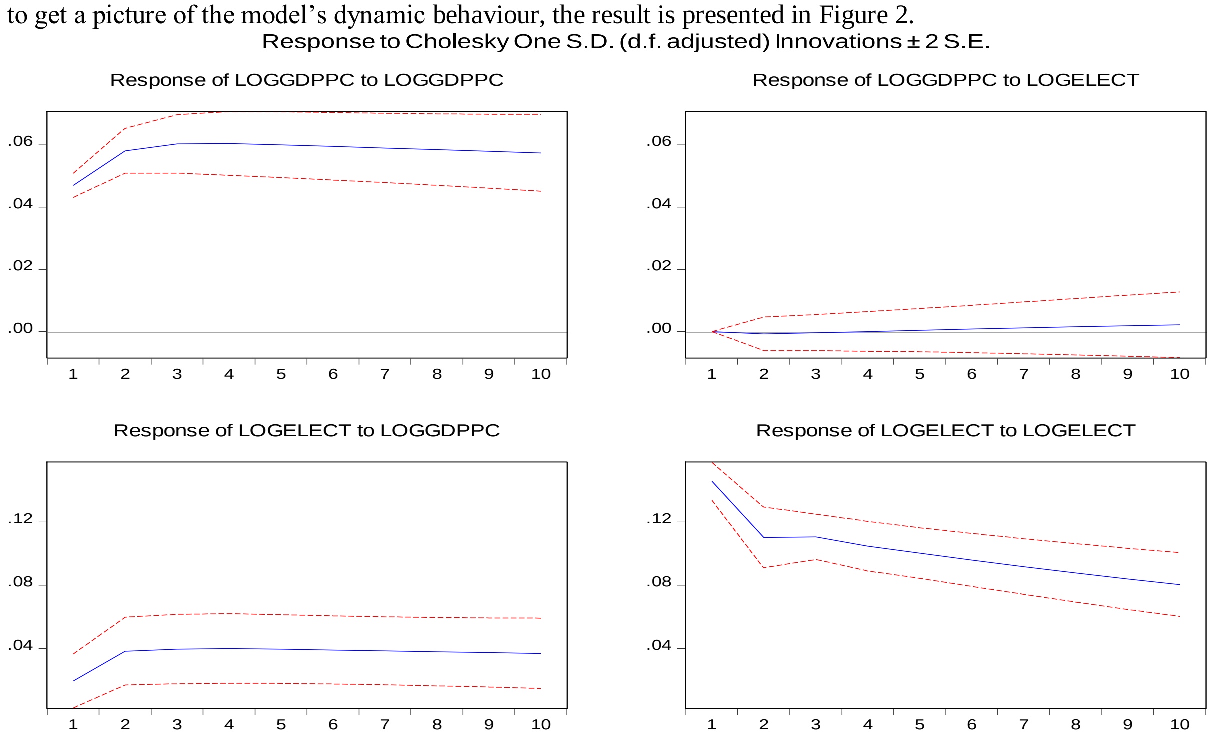

Figure 2: Impulse Response Function

From Figure 2, the impulse response function predicts that a one standard deviation shock to the log of gross domestic product per capita would cause electricity consumption to decline over period 1 to period 2 but remains less responsive to any further shocks over the remaining 8-years period. Similarly, a one standard deviation shock to electricity consumption per capita would cause a steady rise in log of real gross domestic product per capita up to the second period but afterwards, did not respond to any further shocks as it evened out eventually around the third period.

V. Conclusion

The relationship between electricity consumption and economic growth has proved to showcase varying views. This has led the formulation of various thesis such as the electricity-led growth thesis, the growth-driven electricity consumption thesis, the feedback thesis, and the neutrality thesis. This paper examined the influence/relationship of/between electricity consumption and economic growth in West African countries. It was observed that there exists a long run relationship between electricity consumption per capita and gross domestic product per capita. Also, the Dumitrescu-Hurlin Panel Causality Tests indicated the existence of a bidirectional causality between electricity consumption per capita and gross domestic product per capita. This therefore supports the feedback thesis. In examining both the electricity-led growth thesis and the growth-driven electricity consumption thesis, it was observed that both the two theses were valid. Since the two theses were valid, then the feedback thesis is actually true.

The VAR model reported that both electricity consumption per capita and gross domestic product were strongly endogenous however, only electricity consumption was strongly exogenous in predicting gross domestic product per capita. These findings therefore point to the fact that electricity consumption is a critical input in the production function hence, the need to improve electricity generation, transmission, and distribution to feed the needs of the productive sectors of the economy. The development and adoption of alternative energy sources such as solar power needs to be implemented so as to complement the epileptic power supply situations along with the high electricity tariffs inherent in most of the West African countries. The conservation of electricity for the future generation should also be treated as a top priority.

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