International Journal of Energy Economics and Policy
Vol. 1, No. 1, 2011, pp. 18-31
www.econjournals.com

Electricity Consumption-Economic Growth Nexus: The Ghanaian Case

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ABSTRACT: Research into the electricity-economic growth nexus has important implications for energy conservation measures and environmental policy. However, results from the energy-economic growth nexus have been mixed in the literature on Ghana. This posses serious problems for the country's energy policy. Much research is thus, required to establish the direction of causality between energy and economic growth. Nonetheless, less evidence is available for Ghana. It is against this background that this study seeks to investigate the direction of causality between a type of energy, electricity, and economic growth to add to the existing argument in the literature. The Toda and Yomamoto Granger Causality test was used to carry out the test of causality between electricity consumption and economic growth from 1971 to 2008. The results obtained herein revealed that there exists a unidirectional causality running from economic growth to electricity consumption. Thus, data on Ghana supports the Growth-led-Energy Hypothesis. The results imply that electricity conservation measures are a viable option for Ghana.

Keywords: Ghana, Real GDP per capita, Electricity consumption, Toda and Yomamoto, Granger Causality Test, Bounds cointegration
JEL Classifications: Q400, Q430

1. Introduction

Electricity is a key infrastructural element for economic growth. It is a multitalented 'energy currency' that underpins a wide range of products and services that inprove the quality of life, increase worker productivity and encourage entreprenuerial activity. This makes electricity consumption to be positively and highly correlated with real per capita GDP. In Ghana, between 2000 and 2008, while real per capita GDP growth averaged 5.5% per annum, annual electricity consumption growth averaged 1.21%. Inspite of the fact that real per capita GDP and electricity consumption are positively correlated, it is still not clear the direction of causality between real per capita GDP and electricity consumption.

Research into the electricity-economic growth nexus has important implications for electricity conservation measures. However, results spanning from the literature on Ghana have been mixed (see Twerefo et al, 2008; Akinlo, 2008; Lee, 2005; and Wolde-Rufael, 2006). This has serious implications for Ghana's energy policy and environmental policy. Much research is thus, required to establish the direction of causality between electricity consumption and economic growth. However, there is a dearth of research into the electricity-economic growth nexus in Ghana. It is against this background that this study seeks to investigate the direction of causality between electricity consumption and economic growth to add to the existing arguments in the literature using the Toda and Yomamoto Granger Causality Test from 1971 to 2008.

The rest of the paper is organised as follows; chapter two deals with the review of relevant literature and electricity sector and Economic growth in Ghana; chapter three deals with data and methodolog, chapter four provides empirical results while the last chapter concludes and make policy recommendation.

2. Literature Review

The study of the empirical investigations into the causal relationships between energy consumption and economic growth can be analysed through two lines; the hypothesis criteria (Apergis and Payne, 2009) and the generation criteria (Guttormsen, 2004). The hypothesis approach analyses the causation in light of whether studies concluded that electricity consumption causes economic growth or otherwise or both. Along these lines, studies on the empirical investigation into the energy-economic growth nexus have been grouped into four; the Growth-led-Energy hypothesis, the Energy-led-Growth hypothesis, the Energy-led-Growth-led-Energy hypothesis, and the neutrality hypothesis.

The Growth-led-Energy hypothesis asserts that economic growth leads to energy consumption. This implies that even severe energy crisis will not retard economic growth, hence energy conservation measures are a viable option. The Energy-led-Growth hypothesis asserts that energy consumption leads to economic growth. This suggests that severe energy crisis will retard economic growth, hence energy conservation measures are not a viable option. The Energy-led-Growth-led-Energy hypothesis asserts that there exists a bidirectional causality between energy consumption and economic growth. Lastly, the neutrality hypothesis asserts that there is no causal relationship between energy consumption and economic growth.

Along the lines proposed by Guttormsen (2004), studies on the empirical investigations into energy-economic growth have been classified along three lines; the first generation studies, the second generation studies, and the third generation studies. The first generation studies consists of studies that basically used the traditional Vector Autoregressive Models (Sims, 1972) and the standard Granger causality test. The main weakness associated with this generation of studies is that they assume the series to be stationary. As a result the second generation of studies proposed cointegration (Johansen and Juselius, 1990) as the appropriate tool to use in analysing the causal relationship between energy consumption and economic growth. Thus, in the second generation of studies, pairs of variables were tested for cointegration relationship and an error correction model was estimated to test for causality (Engle and Granger, 1987). However, given the possibility of more than one cointegrating vectors, the second generation studies approach was deemed inappriopriaed. This led to the third generation of studies, which proposed a multivariate approach that allowed for more than two variables in the cointegrating relationship. This approach facilitates estimations of systems where restriction on cointegrating relationship can be tested and information on short-run adjustment can be investigated.

There are two main problems with the third generation studies. First, the third generation studies impose restrictions that the variables should be integrated of order one. Secondly, the variables will have to be cointegrated before a test of causality can be possible. This has led to the fourth generation of studies. These studies use the Toda and Yomamoto Granger Causality test, which is based on the Autoregressive distributed lag model. In this generation of studies, restrictions are not imposed on the variables. Thus, causality is still possible even when variables are integrated of order zero, one or both. In other words, this approach allows for the test of causality even when variables are not cointegrated.

In addition to the above, Ozturk (2010) in a literature survey on the energy-growth nexus classified the various studies into country-specific and multi-country studies on energy (electricity consumption) and economic growth. The general obervation according to this study is that the results emanating from the multi-country studies and country-specific studies on the causality between energy consumption and economic growth reveals contracdictory results. However, the results from the country-specific studies on the causality between electricity consumption and economic growth reveals that there exists a positive causality which runs from electricity consumption to economic growth but the multi-country studies on the causality between electricity consumption and economic growth shows contracdictory results. The author therefore, recommeded that to avoid the conflicting and unreliable results, current studies on the causality between energy (electricity) consumption and economic growth should use more recent approaches such as ARDL Bounds cointegration test (Pesarran et al, 2001), threshold cointegration models (Hansen and Seo, 2002), and panel data models. The author also concluded that research papers that use the same methods with the same variables just by altering the data period examined have accounted for the various conflicting results that exist in the literature. As a result, the author advices researchers to desist from such act since such papers do not make any contribution to the existing energy (electricity)-growth literature. Below is a table of summary of works on the causality between energy (electricity) consumption and economic growth.

Table I: Summary of works on the energy (electricity)-growth nexus

Authors / Period	Methodology	Hypothesis	Generation
Kraft and Kraft (1978), 1947-1974,	Standard Granger causality	Growth-led energy U.S.A	First generation
Akarca and Long (1980), 1973-1974,	Standard Granger causality	Growth-led-energy U.S.A	First generation
Yu and Hwang (1984), 1973-1981,	Standard Granger causality	Growth-led-energy south Korea	First generation
Soyatas and Sari (2003), 1950-1992,	Vector error correction model granger causality	Growth-led-energy, Italy, Japan, South Korea	Third generation
Akinlo (2008), 1980-2003	ARDL Bounds test	Neutrality. Nigeria, Cameroon, Ivory Coast, Kenya, Togo	Fourth generation
Wolde-Rufael (2006), 1971-2001,	Toda and Yomamoto granger causality test	Growth-led-energy, Algeria, Congo, Egypt, Ghana, Ivory coast	Fourth generation
Akinlo (2008), 1980-2003	Full Modified OLS	Energy-led-growth-led-energy, Ghana, Gambia, and Senegal	Third generation
Lee (2005), 1975-2001	Vector errror correction model granger causality	Energy-led-growth, Ghana	Third generation
Twerefo et al (2008), 1975-2006	Vector error correction model granger causality	Growth-led-energy, Ghana	Third generation
Fatai et al (2004), 1960-1999	Toda and Yomamoto	Energy-led-growth-led-energy, Philippines	Fourth generation
Stern (2000), 1948-1994	Cointegration, Granger causality	Energy-led-growth, U.S.A	Second generation
Ghali and El-Sakka (2004), 1961-1997	Cointegration, VEC Granger causality	Energt-led-growth-led-energy, Canada	Third generation
Ho and Siu (2007), 1966-2002	VEC Granger causality	Energy-led-growth, Hong Kong	Third generation
Soytas and Sari (2009), 1960-2000	Toda and Yomamoto causality test	Neutrality	Fourth generation
Payne (2009), 1949-2006	Toda and Yomamoto causality test	Neutrality	Fourth generation
Masih (1997), 1952-1992	VEC Granger Causality	Energy-led-growth-led-energy…..Taiwan Energy-led-growth. South Korea	Third generation
ELECTRICITY CONSUMPTION-ECONOMIC GROWTH NEXUS			
Authors / Period	**Methodology**	**Hypothesis**	**Generation of study**
Haciciglou (2007), 1968-2005	Granger causality, Bounds testing	Growth-led-electricity, Turkey	Fourth generation
Tang (2008), 1972-2003	ECM based F-test, ARDL	Growth-led-electricity-led-growth, Malaysia	Fourth generation
Morimoto and Hope (2004), 1960-1998	Standard granger causality	Electricity-led-growth, Sri Lanka	First generation
Shiu and Lam (2004), 1971-2000	Cointegration, ECM	Growth-led-electricity-led-growth, China	Second generation
Odhiambo (2009a), 1971-2006	ARDL Bounds test	Electricity-led-growth	Fourth generation
Odhiambo (2009b), 1971-2006	Standard granger causality	Growth-led-electricity-led-growth, South Africa	First generation
Akinlo (2009), 1980-2006	VEC Granger causality	Electricity-led-growth, Nigeria	Third generation

Ghosh (2009), 1970-2006	ARDL test	Growth-led-electricity, india	Fourth generation
Ghosh (2002), 1950-1997	Standard granger causality	Growth-led-electricity, Indis	First generation
Narayan and Smyth (2005), 1966-1999	Multivariate Granger causality	Growth-led-electricity, Australia	Third generation
Twerefo et al (2008), 1975-2006	VEC Granger causality	Growth-led-electricity, Ghana	Third generation
Wolde-Rufael (2006), 1971-2001	Toda and Yomamoto granger causality test	Growth-led-electricity, Cameroon, Ghana, Nigeria, Senegal, Zambia, Zimbabwe	Fourth generation

As shown in table I above, results spanning from the energy (electricity)-growth nexus have yielded mixed results mainly due to the varying data sets and methodology used and the varying country characteristics. There have been very recent papers on this topical issue, which includes the papers by Acaravci and Ozturk (2010), and Ozturk and Acaravci (2011). Acaravci and Ozturk (2010) using Pedroni panel cointegration investigated the causal relationship between electricity consumption per capita and real per capita GDP for selected 15 transition countries from 1990 to 2006. The authors in this paper found nonexistence of level relationship between electricity consumption per capita and real per capita GDP for the selected transition countries and thus, could not run the causality test. In a related study, Ozturk and Acaravci (2011) using an ARDL Bounds cointegration approach investigated the relationship and the direction of causality between electricity consumption and economic growth for 11 Middle East and North Africa countries (MENA) from 1990-2006. The authors found no unique evidence of long-run equilibrium relationship between electricity consumption and economic growth in Iran, Morocco and Syria, hence, were eliminated from the sample. However, the study found the existence of level relationship between electricity consumption and economic growth for Egypt, Israel, Oman, and Saudi Arabia. The test of causality revealed a one-way short-run Granger causality from economic growth to electricity consumption in Israel. In Egypt, Oman, and Saudi Arabia, the causality test revealed the existence of one-way both short and long-run Granger causality from electricity consumption to economic growth. Generally, the authors concluded that their results suggest that there is weak evidence on the long-run and causal relationship between electricity consumption and economic growth in MENA countries.

Overview of the Electricity Sub-Sector and Economic Growth

Electricity generally passes through three-step phases before getting to the final user. First power is produced from generators which are located far from the load centers. Power is then transferred to the transmission grid, which comprises transmission lines, transformers, and other components, to the bulk load distribution substations. From the bulk load distribution substations power is delivered to the individual customer sites using distribution lines.

In Ghana these three-step process are controlled by three different utility companies. The Volta River Authority (VRA) is a state-owned enterprise that is solely responsible for bulk power generation in the country. Currently VRA operates the Akosombo and Kpong hydro stations which happen to be the major power generation sources in the country. Ghana Grid Company (GRIDCo) is responsible for transmitting power from bulk power plants to distribution lines while Electricity Company of Ghana (ECG) and Northern Electrical Department (NED), a subsidiary of VRA are responsible for distributing power to the final consumer. ECG serves the southern half of the country while NED supplies power to the northern part of the country.

The electricity sector has experienced significant growth over a decade now. In 1992, electricity and water sector recorded a growth rate of 12.02% which was 5.43% higher than the previous year. The primary reason, as reported in the budget statement and economic policy for 1993, included expansions in the national electricity grid under the rural electrification programme and the expansion and up-grading of some urban electricity distribution networks. In 2000, the sector witnessed a growth rate of 4.5% which was below the 1992 figure. In terms of the sectors relative contribution to total industrial growth in the country, the electricity sector contributed 10.21% of total industrial GDP in 2000. In 2005, the sector witnessed an increase in growth rate of 12.4% which translated into the sectors increased relative contribution to total industrial GDP of 11.9%.

However, in 2007, the sector recorded a decrease in growth rate of -17.4% which caused the sector's relative contribution to total industrial GDP to fall to 10.2%. (State of the Ghanaian Economy, 2000-2008). The major reason behind the sectors decreased contribution was mainly due to the serious drought that thumped the Ghanaian economy in 2007 which led to plummet in the water level of Akosombo, the foremost power house for the country.

3. Data and Methodology

Preceeding from the discussion of the empirical literature on energy-growth nexus, the long-run relationship between electricity consumption and economic growth may be specified as below;

$$EC_t = \alpha + \beta Y_t + u_t \text{..........................}(1)$$

Where EC_t is the log of electricity consumption (KWh), Y_t is the log of real per capita GDP (constant 2000 US$) and u_t is the stochastic disturbance term assumed to be white noise. Annual time series data from 1971 to 2008 on electricity consumption and real per capita GDP were sourced from the EnerData Global Energy and CO_2 Data Research Services and Africa Development Indicators correspondingly.

3.1. Unit root test

Although it has been argued in the literature that the ARDL Bounds cointegration tests does not require the pre-testing of series for their order of integration, the need for series to pass two conditions necessitates the need to test for the order of integration of the series. First, the ARDL Bounds cointegration requires that the series in a model should be integrated of an order of either zero or one but not two or more. Secondly, the dependent variable should be integrated of order one.

In this study the Augment-Dickey Fuller unit root test (ADF) and the Phillip-Perron (PP) unit root test are used to ascertain the order of integration of the series. The ADF test is based on the following regression;

$$\Delta z_t = \beta_0 + \alpha_0 T + \alpha_1 z_{t-1} + \sum_{i=1}^{k} \beta_1 \Delta z_{t-i} + \varepsilon_t \text{ ....} (2)$$

Where T is a linear trend, Z is the variable that is being tested for unit root, Δ is the first difference operator and ε_t is the Gaussian white noise term and K is chosen to achieve white noise residuals.

3.2. ARDL Bounds Cointegration Analysis

The ARDL bounds testing approach compared to the other approaches of cointegration has several distinct advantages. One of the main advantages of the ARDL approach in contrast to the Engle and Granger (1987) and Johansen approach (1990) is that the ARDL Bounds cointegration approach permits to test for cointegration regardless of whether the variables are all I (1) or I (0) or a mixture of the two. Secondly, the ARDL Bounds approach is not sensitive to the size of the sample, therefore, making its small sample properties more superior to the multivariate cointegration approach. Lastly, the ARDL approach is known to provide unbiased long-run estimates even when some of the variables are endogenous. Narayan (2005) and Odhianbo (2009) as quoted in Amusa et al (2009) demonstrates that even when some of the independent variables are endogenous, the bounds testing approach generally provides unbiased long-run estimates and valid t-statistics.

Since it is difficult to a priori tell the direction of cointegration between variables, the study in testing for long-run relationships in the variables using the Bounds cointegration test, normalised each variable as a dependent variable. Thus, the following ARDL equations were estimated using OLS and a test of significance on the parameters of the lag level variables were conducted. The resulting F-statistic were then compared to the Pesaran et al asymptotic critical bounds to determine whether there exist a long-run relationship between the variables. Since this is an annual time series, the maximum lag length was set to two. Since a priori it is impossible to determine whether real per capita GDP and electricity consumption can be treated as the 'long-run forcing' variable explaining electricity consumption and real per capita GDP respectively, this study in testing for level relationship excluded the difference level variables of real per capita GDP and electricity consumption in equations (3) and (4).

$$\Delta EC_t = \alpha_0 + \sum_{i=1}^{2} \beta_{iec} \Delta EC_{t-j} + \sum_{i=1}^{2} \gamma_{iec} \Delta Y_{t-j} + \varphi_{1ec} EC_{t-1} + \varphi_{2ec} Y_{t-1} + \mu_{1t} ....(3)$$

$$\Delta Y = \alpha_1 + \sum_{i=1}^{2} \beta_{iy} \Delta Y_{t-j} + \sum_{i=1}^{2} \gamma_{iy} \Delta EC_{t-j} + \varphi_{1y} Y_{t-1} + \varphi_{2y} EC_{t-1} + \mu_{2t} ....(4)$$

From equations (3) and (4) the ARDL Bounds cointegration test involves the test of the following null hypothesis;

$$H_0^{ec} : \varphi_{1ec} = \varphi_{2ec} = 0; \quad H_1^{ec} : \varphi_{1ec} = \varphi_{2ec} \neq 0 \qquad F_{ec}(ec \mid y)$$

$$H_0^{y} : \varphi_{1y} = \varphi_{2y} = 0; \quad H_1^{y} : \varphi_{1y} = \varphi_{2y} \neq 0 \qquad F_{y}(y \mid ec)$$

3.3. Toda and Yomamoto Granger Causality Test

The study of causality has widely been analysed using the vector error correction model (VECM) and error correction model (ECM). However, Toda and Yomamoto (1995) have shown that the asymptotic distribution of the test in the unrestricted VAR has nuisance parameter and nonstandard distribution. Also Toda and Yomamoto (1995), Zapata and Rambaldi (1997) and Rambaldi and Doran (1996) have all reported that approaches such as VECM and ECM used to analyse causality are sensitive to the values of the nuisance parameters in finite samples making the results a bit unreliable. As a result, Toda and Yomamoto (1995) proposed a modification of the Granger causality approach. This approach requires estimating a VAR model in their levels by augmenting the VAR model with the maximum order of integration, d, of the variables in the model. The method then applies the Wald test statistic for linear restrictions to the resulting VAR (K) model. As shown by Toda and Yomamoto (1995), the Wald statistic for restrictions on the parameters of VAR (K) has an asymptotic χ^2 distribution when a VAR (K+d) is estimated (Zapata and Rambaldi, 1997). Thus, the main idea is to intentionally over-fit the causality test underlying model wth additional d lags so that the VAR order becomes (K+d) with K representing the optimal order of the VAR determined by Akaike Information Criterion.

That is when one is uncertain about the order of integration of the variables, augmenting the VAR model with an extra lag usually ensures that the Wald statistic posses the necessary power properties. Thus, in applying the Toda and Yomamoto method, all that is required of one is the maximum order of integration of the variables in the model and the optimal lag order of the VAR (K) model. This method in contrast to the methods of ECM and VECM does not require pre-testing for cointegration and unit root properties and thus, overcomes the pre-test biased associated with the unit root and cointegration test. Also this approach minimises the risk associated with possibly wrongly identifying the order of integration of the series and the presence of cointegration relation (Giles, 1997; Mavrotas and Kelly, 2001).

Given the superiority that the Toda and Yomamoto granger causality has over VECM and ECM, this study adopted the Toda and Yomamoto Granger Causality to test for the direction of causality between electricity consumption and economic growth in Ghana. Thus, the study estimated the following model using the Seemingly Unrelated Regression (SUR) technique. As argued by Rambaldi and Doran (1996), the Wald test experiences efficiency improvements when SURE models are used in the estimation.

$$EC_t = \alpha_0 + \psi_0 T + \sum_{i=1}^{k} \alpha_{1i} EC_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \alpha_{2j} EC_{t-j} + \sum_{i=1}^{k} \beta_{1i} Y_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \beta_{2j} Y_{t-j} + \varepsilon_{1t} ....(5)$$

$$Y_t = \gamma_0 + \psi_1 T + \sum_{i=1}^{k} \gamma_{1i} Y_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \gamma_{2j} Y_{t-j} + \sum_{i=1}^{k} \lambda_{1i} EC_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \gamma_{2j} EC_{t-j} + \varepsilon_{2t} ....(6)$$

Where K is the optimal lag length of the VAR, d_{max} is the maximum order of integration of the variables in the VAR model, EC is the log of electricity consumption, and Y is the log of real per capita GDP. To investigate into the causal relationship between electricity consumption and economic growth, the study estimated equations (5) and (6) using the Seemingly Unrelated Regression and tested the following null hypothesis in equations (5) and (6) respectively.

$$H_0 : \beta_{11} = \beta_{12} = ...\beta_{1k} = 0$$

As against the alternative hypotheses of

$H_A : \beta_{11} = \beta_{12} = ...\beta_{1k} \neq 0$

$H_0 : \lambda_{11} = \lambda_{12} = ...\lambda_{1k} = 0$

As against the alternative hypotheses of

$H_0 : \lambda_{11} = \lambda_{12} = ...\lambda_{1k} \neq 0$

Failure to reject the null hypothesis in equation (5) would imply that real per capita GDP does not lead to electricity consumption. However, failure to accept the null would imply that real per capita GDP leads to electricity consumption. Similarly, in equation (6), failure to accept the null would imply that electricity consumption leads to real per capita GDP. However, failure to reject the null would imply that electricity consumption does not lead to economic growth. In the event that both null hypothesises are accepted, it would imply that neither real per capita GDP and electricity consumption causes the other while failure to accept both null would imply that there exists a bidirectional causality between electricity consumption and real per capita GDP.

4. Empirical results

The study first tested for unit root in variables using the Augmented Dickey Fuller Test and Phillip-Perron Test. The results of the test are shown below in table II.

Table II: unit root test

Variable/test statistic	Intercept and no trend	Intercept and trend	None
EC-ADF	-2.711519**	-3.662053***	0.445793
EC-PP	-2.072651	-2.469109	1.398986
D(EC)-ADF	-5.4060***	-5.321561***	-5.44603***
D(EC)-PP	-7.691418***	-7.421352***	-5.856158***
Y-ADF	-0.538243	-1.185555	1.186281
Y-PP	-0.819665	-1.097411	0.247231
D(Y)-ADF	-4.097168***	-2.035976	-4.12844***
D(Y)-PP	-4.078915***	-6.903395***	-4.121853***

*,**, *** indicates 1%, 10% and 5% levels of significance

From table II above, the test statistics by ADF and PP both reveals that the variables are I (1) at the 5% significant level. Thus, d, which is the maximum order of integration of the variables is one.

4.1. ARDL Bounds cointegration test

Results of the ARDL estimates and joint test of significance are as shown in tables III and IV below.

Table III: Variable Addition Test (OLS case)

Dependent variable is DLNY

List of the variables added to the regression: LNY(-1) LNEC(-1)

35 observations used for estimation from 1974 to 2008

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CON	.17168	.37092	.46285[.647]
DLNY(-1)	.40639	.19154	2.1217[.043]
DLNY(-2)	-.019319	.21313	-.090646[.928]
DLNEC(-1)	-.022149	.036798	-.60191[.552]
DLNEC(-2)	-.021731	.037563	-.57852[.568]
LNY(-1)	-.070699	.077234	-.91539[.368]
LNEC(-1)	.026228	.031428	.83453[.411]

Joint test of zero restrictions on the coefficients of additional variables:

Lagrange Multiplier Statistic	CHSQ(2)= 1.2410[.538]
Likelihood Ratio Statistic	CHSQ(2)= 1.2635[.532]
F Statistic	F(2, 28)= .51465[.603]

From equations (3) and (4), the following null hypothesis were tested respectively

$$H_0 : \varphi_{1ec} = \varphi_{2ec} = 0$$

$$H_0 : \varphi_{1y} = \varphi_{2y} = 0$$

The resulting F-statistic are denoted as $F_{ec}(ec|y) = 5.0226$ and $F_y(y|ec) = 0.51465$ in equations (3) and (4) respectively. Table V shows the Bounds cointegration test.

Table IV: Variable Addition Test (OLS case)

Dependent variable is DLNEC
List of the variables added to the regression: LNEC(-1) LNY(-1)
35 observations used for estimation from 1974 to 2008

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CON	1.5628	1.4787	1.0569[.300]
DLNEC(-1)	.24103	.14669	1.6431[.112]
DLNEC(-2)	-.15761	.14974	-1.0526[.302]
DLNY(-1)	1.9185	.76355	2.5126[.018]
DLNY(-2)	1.4701	.84962	1.7303[.095]
LNEC(-1)	-.38960	.12529	-3.1097[.004]
LNY(-1)	.31218	.30789	1.0139[.319]

Joint test of zero restrictions on the coefficients of additional variables:

Lagrange Multiplier Statistic	CHSQ(2)= 9.2411[.010]
Likelihood Ratio Statistic	CHSQ(2)= 10.7299[.005]
F Statistic	F(2, 28)= 5.0226[.014]

Table V: Bounds cointegration test

F-statistics	**10% level of significance**		**5% level of significance**	
	Lower Bound	**Upper Bound**	**Lower Bound**	**Upper Bound**
$F_{ec}(ec|y) = 5.0226$	2.49	3.38	2.81	3.76
$F_y(y|ec) = 0.51465$				

From table V above, the F-statistic from equation (3) exceed the 5% upper critical bound while the F-statistic from equation (4) falls below the lower critical bounds. It can be concluded that the lag level variables Y and EC are significant in the electricity consumption equation. Thus, there exist a long-run relationship between electricity consumption and real per capita GDP. In other words, real per capita GDDP (Y) can be treated as the 'long-run forcing' variable explaining electricity consumption. However, the lag level varaiables, Y and EC are not significant in the real per capita GDP equation. Thus, there exist no long-run relationship between real per capita GDP and electricity consumtpion and therefore, electricity consumption cannot be treated as the 'long-run forcing' variable explaining real per capita GDP.

4.2. Causality Test

The next stage involved the test of causality between electricity consumption and real per capita GDP. First the study tested for the appropriate oder of the VAR using the Akaike Information Criterion. Results of the test suggest a lag length order of two. Also a test of inclusion or exclusion of deterministic variables in the VAR were conducted. The LR test of deletion of deterministic variables in the VAR follows the chi-square distribution. Results of the test suggest the inclusion of an intercept and a time trend in the VAR. Details of these tests are shown in the tables VI and VII below.

Table VI: Test Statistics and Choice Criteria for Selecting the Order of the VAR Model

Based on 34 observations from 1975 to 2008. Order of VAR = 4
List of variables included in the unrestricted VAR: LNEC LNY
List of deterministic and/or exogenous variables: CON T

Order	LL	AIC	SBC	LR test	Adjusted LR test
4	86.0247	66.0247	50.7611	------	------
3	81.4585	65.4585	53.2476	CHSQ(4)= 9.1325[.058]	6.4465[.168]
2	78.6086	66.6086*	57.4505	CHSQ(8)= 14.8322[.062]	10.4698[.234]
1	71.6420	63.6420	57.5365*	CHSQ(12)= 28.7655[.004]	20.3051[.062]
0	24.9291	20.9291	17.8764	CHSQ(16)= 122.1912[.000]	86.2526[.000]

NB: AIC and SBC in Microfit are based on log-likelihood hence the maximum is chosen.

Table VII: LR Test of Deletion of Deterministic/Exogenous Variables in the VAR

Null hypothesis	**LR test of restrictions (CHSQ)**	**Maximum value of log-likelihood**	**P-value**
Intercept but no trend	10.0772	74.5430	0.006
No intercept but trend	3.3864	77.8884	0.184
Intercept and trend	11.0271	74.0680	0.026

This study first adopted the LR test of Block Granger Non-causality in the VAR. The LR test of Block Granager Non-causality statistic tests the null hypothesis that the coefficients of the lagged values of the variables assumed to be 'non-causal' in the block of equations explaining other variables are zero. The results of the LR test of Block Granger Non-causality are shown in the table VIII below;

Table VIII: LR Test of Block Granger Non-causality in the VAR

Null Hypothesis	LR statistic	Decision
Electricity consumption does not cause real per capita GDP	2.5074	Do not reject the null
Real per capita GDP does not cause electricity consumption	9.0107***	Fail to accept the null

***Indicates 5% level of significance. The maximum lag length is 2

As shown in table VIII above, the LR test of Block Granger Non-causality shows that there exist a unidirectional causality running from real per capita GDP to electricity consumption. Having established the optimal lag length to include in the VAR, the maximum order of integration and inclusion of an intercept and a time trend, the study proceeded to estimate the following VAR model using the Seemingly Unrelated Regression model.

$$EC_t = \alpha_0 + \phi T + \sum_{j=k+1}^{3} \alpha_{1j} EC_{t-j} + \sum_{j=k+1}^{3} \beta_{1j} Y_{t-j} + \varepsilon_{1t} \qquad (6)$$

$$Y_t = \gamma_0 + \psi T + \sum_{j=k+1}^{3} \gamma_{1j} Y_{t-j} + \sum_{j=k+1}^{3} \lambda_{1j} EC_{t-j} + \varepsilon_{2t} \qquad (7)$$

Where k = 2 and d_{max} = 1. Results of the estimation of equations (6) and (7) are as shown in tables IX and X below.

Table IX: Seemingly Unrelated Regressions Estimation.
The estimation method converged after 0 iterations

Dependent variable is LNEC. 34 observations used for estimation from 1975 to 2008

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CON	1.3649	1.7005	.80260[.429]
T	-.0013122	.0056366	-.23280[.818]
LNEC(-1)	.85776	.18428	4.6547[.000]
LNEC(-2)	-.39723	.22722	-1.7483[.092]
LNEC(-3)	.16750	.16764	.99921[.327]
LNY(-1)	2.3465	.89941	2.6089[.015]
LNY(-2)	-.50993	1.3553	-.37624[.710]
LNY(-3)	-1.5100	.97562	-1.5477[.134]

R-Squared	.79376	R-Bar-Squared	.73823
S.E. of Regression	.19318	F-stat. F(7, 26)	14.2953[.000]
Mean of Dependent Variable	8.3997	S.D. of Dependent Variable	.37758
Residual Sum of Squares	.97031	Equation Log-likelihood	12.2166
DW-statistic	2.1912	System Log-likelihood	81.4585
System AIC	65.4585	System SBC	53.2476

Table X: Seemingly Unrelated Regressions Estimation.
The estimation method converged after 0 iterations

Dependent variable is LNY. 34 observations used for estimation from 1975 to 2008

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CON	.78017	.32027	2.4360[.022]
T	.0043641	.0010616	4.1110[.000]
LNY(-1)	.96366	.16939	5.6890[.000]
LNY(-2)	-.24802	.25525	-.97164[.340]
LNY(-3)	.18140	.18374	.98726[.333]
LNEC(-1)	-.016489	.034706	-.47511[.639]
LNEC(-2)	-.0061151	.042793	-.14290[.887]
LNEC(-3)	-.014059	.031572	-.44531[.660]

R-Squared	.94288	R-Bar-Squared	.92751
S.E. of Regression	.036383	F-stat. F(7, 26)	61.3163[.000]
Mean of Dependent Variable	5.4787	S.D. of Dependent Variable	.13513
Residual Sum of Squares	.034417	Equation Log-likelihood	68.9807
DW-statistic	1.4142	System Log-likelihood	81.4585
System AIC	65.4585	System SBC	53.2476

The test of Toda and Yomamoto granger causality then imposes restrictions on the first K-lags of the variable assumed to be non-causal in the equation. From equations (5) and (6), this study tested for the following null hypothesis based on the Wald test respectively;

$H_0 : \beta_{11} = \beta_{12} = 0$

As against the alternative hypothesis;

$H_A : \beta_{11} = \beta_{12} \neq 0$

And

$H_0 : \lambda_{11} = \lambda_{12} = 0$

As against the alternative hypothesis;

$H_A : \lambda_{11} = \lambda_{12} \neq 0$

Results of the Wald tests are shown below;

Table XI: Wald test of restriction(s) imposed on parameters in equation 5

The underlying estimated SURE model is: lnEC CON T lnEC {1-3} lnY {1-3}; lnY CON T lnY {1-3} lnEC {1-3}.
34 observations used for estimation from 1975 to 2008
List of restriction(s) for the Wald test: A6=0; A7=0
Wald Statistic CHSQ(2)= 10.8149[.004]

Table XII: Wald test of restriction(s) imposed on parameters in equation 6

The underlying estimated SURE model is: lnEC CON T lnEC {1-3} lnY {1-3}; lnY CON T lnY {1-3} lnEC {1-3}.
34 observations used for estimation from 1975 to 2008
List of restriction(s) for the Wald test: B6=0; B7=0
Wald Statistic CHSQ(2)= .72479[.696]

The sumary of the resulting test are as shown in table XIII below.

Table XIII: Wald statistic

Null Hypothesis	Wald statistic	Decision
Electricity consumption does not cause real per capita GDP	0.72479	Do not reject the null
Real per capita GDP does not cause electricity consumption	10.8149***	Fail to accept the null

***Indicates 5% level of significance.

From the results shown in table XIII, it can be concluded that there exists a unidirectional causality running from real per capita GDP to electricity consumption. Thus, data on Ghana supports the Growth-led–Electricity hypothesis. The results obtained herein confirms the conclusions reached by Wolde-Rufael (2006) and Tweredfo et al (2008) but contradicts the conclusions reached by Akinlo (2008) and Lee (2005).

The results obtained herein can be explained in two possible ways. First, electricity as an energy type constitutes the smallest share in terms of national energy consumption in Ghana. Largely, growth in total energy consumption is heavily dictated by the patterns of biomass and petroleum consumption, with biomas explaining about 70% of the variations in total energy consumption. Thus, given the relatively small share of electricity consumption in total energy consumption, electricity consumption is not expected to be a major determinant of energy consumption, hence economic growth.

Secondly, the most productive sectors (agricultural and service sectors) in the Ghanaian economy are less energy intensive. The structure of the distribution of domestic electricity consumption has tilted away from the industrial sector towards the residential sector. Coupled with the declining industrial growth, the industrial sectors contribution to national output is now minimal. Thus, the industrial sector (the most energy intensive sector), which is preordained to be the channel through which electricity consumption leads to growth is now on the decline. This suggests that even when there are severe energy crisis, the most productive sectors in the economy are less likely to be affected. For instaince, the severe energy crisis experienced in 2006/2007 did not sway the economy from achieving her macroeconomic targets. The economy amidst the energy crisis realised a macroeconomic growth target of about 6.2 percent, which was 0.2 percent higher than the target (Budget Statement, 2007, Ghana).

5. Conclusions and Policy Recommendations

The study investigated into the direction of causality between electricity consumption and economic growth using the Toda and Yomamoto Granger Causality test from 1971 to 2008. The ARDL Bounds test of cointegration revealed that there exists a long-run relationship between electricity consumption and real per capita GDP and that real per capita GDP can be treated as the 'long-run forcing' variable explaining electricity consumption.

The test of causality between electricity consumption and real per capita GDP based on the Toda and Yomamoto Granger Causality test revealed that data on Ghana supports the Growth-led-Electricity Hypothesis. The results herein imply that electricity conservation measures are a viable option for Ghana. As a result there would be the need to develop and intensify appropriate electricity conservation measures in the Ghanaian economy since this will not retard growth in the economy.

Acknowledgement

I would like to express my heartfelt appreciation to two anonymous referees and the editor whose positive comments and suggestions have perk up the earlier version of this paper. Any other error spotted in this work is the fault of the author.

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