Economic growth and energy consumption in an emerging economy: augmented granger causality approach

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Abstract

This study investigates casual relationship and the magnitude of impact between economic growth (GDP growth) and energy consumption[a] in an emerging economy. The study employs Sims (1972) test based on Granger's (1969) definition of causality. Quarterly data spanning a period of 39 years is used in this empirical analysis. Granger Causality tests shows there exist unidirectional causal relationship between economic growth (GDP growth) and energy consumption in this emerging economy; with direction of causality running from economic growth to energy consumption. Test results further indicate a percentage growth in GDP induces approximately 2% growth in electric energy consumption all things being equal.

Keywords: Economic Growth, Energy Consumption, Causality, Emerging Economy.

[a] The study presumes energy consumption in this emerging economy equals electric energy consumption, since electric energy is the dominant source of energy in Ghana.

1 INTRODUCTION

Economic growth continues to be a key macroeconomic concept of interest among most researchers and policy makers around the world. The sustain interest in this macroeconomic indicator stems from its pivotal role in impacting other integral segment of an economy and livelihoods. Our understanding of the dynamics responsible for economic growth and the factors which impact this growth continue to evolve as economic boundaries continue to fade in the face of increasing shift towards integrated global economy. Ongoing studies over the years have identified and continue to isolate critical factors which tend to shape and influence changes in this all important macroeconomic variable (economic growth or GDP growth). A host of factors have so far been identified as the key elements explaining variability in economic growth among economies around the world. In his celebrated work on the core factors influencing economic growth, Robert Solow (1956) isolated a key exogenous factor which significantly impact growth potential among economies. Legion of empirical studies after Solow's work have significantly increase our understanding of the dynamics of economic growth and the key evolving factors responsible for differential growth among developed and developing economies around the world.

Solow's work identified this exogenous growth factor as technological progress or advancement. Studies focusing on economic growth since Solow's ground breaking work have confirmed the importance of this key exogenous variable in the economic growth process. Consequently, the notion that economic growth significantly correlates with thriving technological advancement is no longer in dispute. This augmenting relationship between technological advancement and economic growth has further been supported by significant volume of empirical studies which have verified the condition among most developed and developing economies around the world; Mokyr J (2005), Ali F. Darrat and Saif S. AL-Sowaidi (2010). However, it is cogent to point out that as critical as advances in technology might be in the economic growth process; such advances constitute only a necessary integral condition; advances in technology by itself are not sufficient in the economic growth process. Growing number of researchers have pointed out that efficient energy supply or availability (a core ingredient in technological advancements) constitutes the bedrock and the engine driving growth among economies around the world through technology; Murillo-Zamorano, Luis R (2005). In other words the pendulum of productivity sustaining economic growth is perceived to be set in motion by technological advancement with dependable energy supply as the press button.

Identifying and managing the relationship between these key variables (economic growth (GDP) and energy supply (consumption)) is thus critical in understanding an economy's future growth trajectory and standard of living of its populace. The ever growing demand and virtual dependence on energy due to technology driven lifestyles of the twenty-first century further makes an enquiry into mechanisms linking these key variables a timely one. Existing studies aimed at understanding the link between these critical variables have all to some extent established condition of positive correlation between the variables. Ongoing research has further helped in documenting the direction of causal relationship between the variables among most economies around the world; and the extent to which the variables augment each other (Nicholas Apergis, James E. Payne, 2010). Results from existing empirical studies, however, also show that the direction of causality between energy supply (consumption) and GDP growth tend to differ significantly from economy to economy; the variation is even more profound among emerging economies around the world. Existing literature further documents that varied country-specific features associated with developed and developing economies significantly impact direction of causality between economic growth and energy consumption (Imran Kashif and Siddiqui Masood Mashkoor, 2010), (Ebohon Obas John, 1996). This study goes beyond perceived correlation between economic growth and energy consumption to test for the direction of causality between these core variables in the case of Ghana, an emerging Sub-Sahara African economy. Additionally, this study further estimates the magnitude of influence exerted by the identified causal variable in the study, an approach often neglected in current studies.

2 Economic Growth and Energy Consumption (Supply) in Ghana

Political stability and favorable socio-economic conditions continue to spur modest but sustained economic growth in this emerging Sub-Sahara African economy. The trend however, has often been constrained by perennial subpar energy supply plaguing this fledgling economy. Like most economies in the sub-region, the country's energy production rate continues to lag behind the rate of growth in demand from its industrial and services sectors. Population growth coupled with expansion in production activities due to increasing foreign direct investment continue to put enormous strain on the main electric energy generating systems built in the 1960s. With energy supply lagging behind growing consumption, rationing of electric energy in most central business districts continue to be the norm (Anaman Kwabena, 2006). This unfolding trend often raises concern about the ultimate impact of the condition on the economy's drive towards enhancing productivity, growth and standard of living of its populace. Although electric energy generation and supply difficulties in the country over the years are well documented, worsening supply conditions continue to heighten growing concerns in recent years about the ultimate impact of the condition on the nation's long-term economic growth prospects and quality of life. Even though most policy makers tend to recognize the potential negative impact of the precarious energy supply condition on this budding economy, the concerns are mostly based on presumed correlation between the two variables. Views on the direction of causal relationship between the variables and the magnitude of impact actually exerted tend to vary significantly among policy makers.

The anemic energy supply condition in the country against ever-expanding industrial and services sectors as noted above raises critical empirical questions. Apart from perceived correlation between the two variables, this study seeks to verify if there exist statistically verifiable causal relationships between economic growth and energy supply (consumption). Ordinarily, there seems to be consensus on the notion that energy supply (consumption) and GDP growth are related at some level (UN Energy Demonstration Study, 2006). This consensus tends to foster the belief that frequent energy supply fluctuations will endanger ongoing and future economic growth prospects. However, there is a fundamental problem with this conclusion (perceived energy generation difficulties and negative economic growth prospect). The key deficiency with this linkage stems from the fact that the general consensus is predicated on assumed (not empirically verified) causal relationship between the two variables.

Supporters of the positive link between the two variables projects that, sustained energy supply enhances productivity which ultimately promotes economic growth. Thus to these proponents, energy supply (consumption) granger causes economic growth in this emerging economy all things being equal (Yemane Worlde-Rufael, 2004). However, as indicated earlier, available literature on this emerging economy provide little or no compelling empirical evidence (as far as a search of available literature is concern) in support of this view; and the magnitude of the effect. The goal of this study is to employ relevant data to verify this presumed condition which seems to be accepted as fact among some policy makers. Although this presumed causal link between the two variables sounds convincing given the immense contribution of energy to economic growth, it does not necessarily lends credence to the fact that energy consumption in the Ghanaian economy necessarily granger causes growth in GDP or economic growth. There is significant empirical evidence in the literature to the effect that the direction of causality between the two variables could also run from economic growth to growth in energy consumption or the causal effect could be bidirectional (Bartleet, Matthew and Rukmani Gounder , 2010), (Belke at al, 2010).

In order to ascertain relative causal relationship between energy consumption and economic growth, this study subjects the variables to series of statistical tests in an attempt to answer the following questions: First, this study seeks to verify if available data supports perceived notion alluded to above regarding positive relationship between energy consumption and economic growth. Second, it also seek to ascertain if there exist a verifiable causal (as defined by Granger – 1969) relationship between electric energy consumption and economic or GDP growth; and the direction of causality between the variables. Additionally, the study also tests for the magnitude of influence exerted by a causal factor on the other variable if causal relationship is ultimately established. The study employs time series data on electric energy consumption and GDP growth from the Ghanaian economy spanning a period of 39 years[b]. (Data is converted into quarterly time series format).

The rest of the study is structured as follows: The second section following the above analysis reviews relevant literature on causal relationship between economic growth and electric energy consumption (supply). The section also tracks varied conclusions reached in these studies in order to assess if the frequency of identified direction of causality favors a particular variable in the GDP growth and energy consumption nexus. Section three conducts series of tests crucial in ascertaining the direction of causality between the core variables of the study. This section tests the time series variables employed in this study for unit root, conducts granger causality test, and measures the magnitude of influence exerted by the potential causal variable if the relationship is verified using ordinary least square regression. Finally, section four presents findings of the study, policy implications and potential managerial applications.

[b] Data Source: United Nation Statistical Database.

3 Literature Review

Electric energy consumption, a substantial component of total energy consumed by economies around the world, has been the backbone of most economic activities for decades. The crucial role played by electric energy as a key driver of economic activities is well documented in available literature. Existing literature have for instance shown that electric energy constitutes an important factor driving productivity associated with various sectors of an economy in most economies around the world (Atif, Syed Muhammad and Siddiqi Muhammad Wasif, 2010). Sustained economic growth has also been shown to be mainly possible under condition of sustained energy supply all things being equal. Ongoing studies focusing on the relationship between energy consumption and economic growth have provided sufficient evidence highlighting the importance of energy consumption (supply) in the economic growth process. For instance, Galip Altinay and Erdal Karagoal (2005), investigated causal relationship between electric energy consumption and economic growth in Turkey for the data period 1950 to 2000. Granger causality test conducted showed strong evidence of unidirectional causal relationship between electric energy consumption and economic growth, with direction of causality running from electric energy consumption to income or GDP growth. In other words, given sustain supply, electric energy consumption is found to be crucial in sustaining appreciable economic growth in Turkey.

Seung-Hoon Yoo (2004) analyzed short and long run causal relationship between electric energy consumption and economic growth in the Korean Republic using co-integration and error correction procedures. Yoo's study showed that there exist bi-directional causal relationship between electric energy consumption and economic growth in the Korean economy. Yoo's analysis showed that growth in electric energy consumption directly promotes economic growth through expansion in energy dependant economic activities; and sustained economic growth in the process also stimulates electric energy consumption. The study however failed to point out the original causal variable in the energy consumption economic growth nexus.

Furthering of his work on causal relationship between electric energy consumption and economic growth, Seung-Hoon Yoo (2005) extended his analysis on the relationship between the two variables to four of the ASEAN (Association of south East Asian nations) economies. Yoo's study in this instance had varied outcomes. The study found bi-directional causal relationship between electric energy consumption and economic growth in the case of Malaysia and Singapore. The study however, found unidirectional causal relationship in the case of Thailand and Indonesia with the direction of causality running from economic growth to electric energy consumption; that is, within these two economies (Thailand and Indonesia) economic growth rather stimulates or granger causes growth in electric energy consumption.

Sheng-Tung Chen, Hsiao-I Kuo and Chi-Chung Chen (2006), provided broader analysis on the relationship between electric energy consumption and economic growth. The study engaged ten newly industrialized and developing Asian countries using both single and panel data sets. The study showed that direction of causal relationships among economies varies significantly from economy to economy; a condition which suggests the role of unique country specific factors. For instance, Shen-Tung et al found unidirectional short-run causal relationships running from economic growth to electric energy consumption among some of the economies studied; other economies however exhibited bi-directional long-run causal relationship between electric energy consumption and economic growth.

Contribution to the literature on the relationship between electric energy consumption and economic growth, Jay Squalli (2006) focused primarily on OPEC countries. His investigation provided sufficient evidence in support of a long-run relationship between electricity consumption and economic growth for almost all OPEC member countries. Causality test showed that economic growth is dependent on electricity consumption in five of the countries in the cartel; less dependent in three of the economies, and independent in the rest of the countries tested in the study. Seung-Hoon Yoo and Yeonbae Kim (2006) investigated how Indonesia's economy could meet its electric energy supply in the face of growing domestic demand. Test for causal relationship between electricity generation (consumption) and economic growth found unidirectional causal relationship running from economic growth to electricity generation (consumption) without any feedback. That is, economic growth granger causes growth in electric energy consumption in the case of Indonesia. This study thus confirmed Seung-Hoon Yoo (2005) conclusion on the causal relationship between electric energy consumption and economic growth in Indonesia.

Aitor Ciarreta and Aihoa Zarraga Alonso (2007) tested for both linear and non-linear causal relationship between electric energy consumption and economic growth in the case of Spain for the period 1971 to 2005. Using the Toda Yamamoto (1995) methodology after accounting for data stationality, the study found unidirectional linear causal relationship between the variables, with direction of causality running from GDP growth to growth in electricity consumption. The study however, failed to document any evidence of nonlinear Granger causal relationship between the variables in either direction. Haipeng Wang, Peng Tian, Ping Jin (2005) applied cointegration and error correction model to examine the causal relationship between electricity consumption and economic growth within the Chinese economy for the period 1953 to 2003. Final study estimates showed that real GDP and electricity consumption in China are cointegrated, and the trend exhibits unidirectional causality running from electricity consumption to real GDP growth. In a related study on the relationship between electricity consumption and real GDP growth in China, Alice Shiu and Pun Lee Lum (2003) also showed that real GDP and electricity consumption in China are cointegrated. This study also found unidirectional granger causality running from electric energy consumption to real GDP growth. Additionally, focusing on the electric energy consumption and GDP growth nexus in the case of the Fuji Island, Paresh Kumar Narayan and Baljeet Singh (2006) tested for the linkage between the variables using multivariate framework which included labor force variable. The goal was to ascertain the extent to which the electric energy consumption and labor force variable cointegrate with GDP growth. Granger causality test conducted found a long-run causal relationship running from electricity consumption and labor force to GDP growth.

Yemane Wolde-Rufael (2004) tested long-run causal relationship between electricity consumption per capita and real gross domestic product (GDP) per capita for 17 African countries for the period 1971 to 2001. The study employed cointegration test proposed by Pesaran et al. (2001) and a modified version of Granger causality test developed by Toda and Yamamoto (1995). Results of this empirical work showed that there exist a long-run relationship between electricity consumption per capita and real GDP per capita among 9 of the countries studied and Granger causality for 12 countries out of the 17 studied. The study further found positive unidirectional causal relationship for 6 countries running from real GDP per capita growth to electricity consumption per capita; an opposite causality for 3 of the countries (that is causality running from electricity consumption to gdp per capita), and bi-directional causal relationship for the remaining 3 countries. This study showed that despite the overwhelming evidence of long-run relationship between economic growth and electric energy consumption, direction of causality could vary significantly.

Sajah Ghosh (2002) examined causal relationship between electricity consumption per capita and GDP per capita for India using annual data covering the period 1950-51 and 1996-97. Ghosh work failed to find any long run equilibrium relationship between the variables; the study however found unidirectional granger causality running from economic growth to electricity consumption without any feedback effect. S.F Ghaderi, M A Azedah and S Mohammadzadeh (2006), studied the relationship between electricity consumption and value added (economic growth) in Iran for the period between 1980 and 2001; causality test show that electricity consumption in Iran does not have much impact on value added among most industries and for that matter economic growth. Enebeli Emmanuel Emeka (2010) investigated the existence and direction of granger causality between electricity consumption and economic growth in Nigeria using the annual data covering the period 1978 to 2008. Empirical results established granger causality between electric energy consumption and economic growth with direction of causality running from economic growth to electricity consumption without any feedback effect.

4 Data and Theoretical Framework

This study employs three methods in examining causal relationship between electricity consumption and GDP growth; and the magnitude of the effect for the Ghanaian economy (an emerging economy). In order to control and capture seasonal fluctuations in electric energy generation in the test for causal relationship between electric energy consumption and economic growth, data on the core variables have been converted into quarterly series. Electric energy consumption and GDP growth data are sourced from the United Nations country database. The rest of this section is organized as follows: First, electric energy consumption and GDP growth variables are tested for unit root to establish the extent to which the variables meet necessary stationary conditions. Second, Granger causality test is conducted to ascertain direction of causality if any, between the two core variables in this study. Finally, simple OLS regression test is conducted to measure the magnitude of influence exerted by the identified causal variable if causal relationship is established.

To overcome a possible occurrence of spurious regression results due to non-stationary time series data, this study verifies stationary conditions of the test variables. The goal is to show that the variables (GDP growth and electric energy consumption) are integrated in the order I(0) or a linear combination of the variables are cointegrated in a similar order; Engle and Granger,(1987)[c]. Stationary properties of electric energy

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[c] Following procedure suggested by Engle and Granger(1987) and addressed in Gujarati (1995)

consumption and GDP growth variables are evaluated using the Augmented Dickey-Fuller Unit root test procedure. Granger causality test is conducted using F-test manipulation of ordinary least square regression analysis. Choice of appropriate lag time use in conducting Augmented Dickey-Fuller test as well as Granger causality test is based on the Akiake Information Criterion (AIC) procedure and the Schwartz/Bayesian Information Criterion (SBIC). The following section presents the framework for various tests conducted; empirical findings and conclusion, and policy implications of this study's findings.

5 Unit Root Test

Equations 1 and 2 models test for stationary conditions for electric energy consumption and GDP growth variables employed in this study. Unit root test functions are formulated as follows:

$$X_1 = ß_1 + ß_2 t + \delta X_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta X_{t-i} + \varepsilon \qquad (1)$$

$$Y_1 = ß_1 + ß_2 t + \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \varepsilon \qquad (2)$$

Where $ß_1$ is the constant term, t, the trend variable, X and Y reflects the two key variables been tested and ε is the error term. (δX_{t-1}) *and* (δY_{t-1}) are lagged values of X and Y variables (GDP growth and electric energy consumption) respectively. The null hypothesis of unit roots (non stationary variables), ie $X(Y)= 1$ is tested against the alternative hypothesis that $X(Y)$ is equal to zero. Tables 1 and 2 in the appendix presents the outcome of unit root tests for electric energy consumption and GDP growth variables using Augmented Dick-Fuller unit root test procedure. Test results indicates the two variables are integrated I(0) affirming stationary conditions for the variables on individual trends. This unit root test outcome guarantees that final regression results based on test variables in their current state will not produce spurious regression results, a condition normally associated with unit root or non stationary variables.

Test statistic presented in Table 1 (Appendix) is less than the critical values at 1%,5% and 10% levels; consequently the null hypothesis of unit root is rejected (GDP growth variable is stationary)

Additionally, resultant test statistic in table 2 (Appendix) is also less than the critical values at 1%,5% and 10% levels; the null hypothesis of unit root is also rejected. (Electric energy consumption variable is stationary).

6 Economic Growth and Energy Consumption: Granger Causality Test

Having verified stationary conditions of core variables in this study, (variables are integrated in the order I(0)), Granger Causality test is conducted to verify the presence of causal relationship between electric energy consumption and economic growth in this emerging economy. Granger Causality test is based on a simple technique which suggest that, if condition X, is observed to normally or frequently occur after the realization of condition Y, then it could be presumed that condition Y might have influence or cause occurrence of condition X all things being equal. In order words, if variable X cause changes in Y, then one will ordinarily observe that changes in X will tend to precede changes in Y, because if X causes Y, it is highly improbable that Y will occur before X, its causal variable. To test for direction of causality between the two study variables using the Granger Causality framework, two (four) equations are stated. In each equation the current value of the dependent variable (X or Y) is modeled as a function of the other (independent) variable as well as lagged values of the dependent variable itself using lagged period determined by Akaike Information Criterion. If lagged variables of X for instance, are found to significantly impacts, influences or cause changes in current values of Y, then it can be concluded that variable X Granger causes changes in Y and vice versa all things being equal. The following linear equations model the Granger causality test process. The test process employs Sims (1972) test based on Granger's (1969) definition of causality.

Let Y represent electric energy consumption growth and X, GDP growth. The condition that electric energy consumption granger causes GDP growth could be modeled as follows:

$$X_1 = ß_0 + ß_1 X_{t-1} + ß_2 X_{t-2} + \ldots ß_3 X_{t-p} + \delta Y_{t-1} + \delta Y_{t-2} + \ldots \delta Y_{t-p} + \varepsilon \qquad (3)$$

$$X_1 = ß_0 + ß_1 X_{t-1} + ß_2 X_{t-2} + \ldots\ldots ß_3 X_{t-p} + \varepsilon \qquad (4)$$

Where X_{t-1} *and* X_{t-2} are lagged values of GDP growth and Y_{t-1} *and* Y_{t-2} are lagged values of electric energy consumption respectively. Unrestricted regression in equation 3 tests the null hypothesis that Y does not granger causes changes X or growth in energy consumption does not granger causes growth in GDP as follows:

$$H_o: \delta_1 + \delta_2 + \ldots \delta_3 = 0 \qquad (5)$$

Equation 4, is the restricted regression.

$$Y_1 = \delta_0 + \delta_1 Y_{t-1} + \delta_2 Y_{t-2} + \ldots \delta_3 Y_{t-p} + ß_1 X_{t-1} + ß_2 X_{t-2} + \ldots \ldots ß_3 X_{t-p} + \varepsilon \qquad (6)$$

$$Y_1 = \delta_0 + \delta_1 Y_{t-1} + \delta_2 Y_{t-2} + \ldots \delta_3 Y_{t-p} + \varepsilon \qquad (7)$$

Equation 6, an unrestricted regression equation tests the null hypothesis that X does not granger causes changes Y or GDP growth does not granger cause changes in electric energy consumption as follows:

$$H_o: ß_1 + ß_2 + \ldots ß_3 = 0 \qquad (8)$$

Equation 7, is alternate restricted regression

To test the main hypotheses in equations 5 and 8, this study relies on Sims (1972) manipulation of F-statistics using equations (3) and (6) the unrestricted functions.

If final test results indicates equation 5 holds true, that is, lagged values of electric energy consumption does not influence or granger cause changes in GDP growth, then it could be concluded that $\mathcal{Y}$ does not granger cause variations in $\mathcal{X}$ or $\mathcal{Y}$ does not influence changes in $\mathcal{X}$. Thus, electric energy consumption does not granger cause changes in GDP growth. In the same vein if equation 8 is true, then $\mathcal{X}$ does not granger cause changes in $\mathcal{Y}$; leading to the realization that growth in GDP does not granger cause growth in electric energy consumption. However, if results show that equation 8 holds true but equation 5 does not, then the condition suggests $\mathcal{Y}$ granger causes or influence changes in $\mathcal{X}$; leading to the conclusion that electric energy consumption granger causes growth in GDP all things being equal. On the other hand if equation 5 is verified to be true but equation 8 is not, then the condition suggests that growth in GDP granger causes growth in electric energy consumption. Additionally, if both equations (equation 5 and 8) do not hold true then there is a bidirectional causal effect or relationship between GDP growth($\mathcal{Y}$) and growth in electric energy consumption($\mathcal{X}$) (feedback effect). Finally, if both equations hold true then the two variables are deemed to be independent of each other. Table 3 (Appendix) presents summary of possible causality test outcomes.

7 Empirical Results, Policy Implications

Table 4 (Appendix) present results of Granger Causality test between growth in electric energy consumption and GDP growth based on seasonally adjusted quarterly data. The first test, electric energy consumption growth does not granger causes gross domestic product growth is insignificant. However, the second procedure which tests the condition that GDPG does not cause changes in EECG is significant. The null hypothesis that GDPG does not granger causes changes EECG is rejected in the second test. Consequently, this study concludes that growth in gross domestic product granger causes growth in electric energy consumption in this emerging economy, all things being equal. In other words GDP growth in the Ghanaian economy rather generates or promotes growth in electric energy consumption with no feedback effect. This outcome as noted earlier is inconsistent with prevailing notion on presumed causal relationship between electric energy consumption and GDP growth. Prevailing views on the ultimate impact of the precarious electric energy supply conditions in the country seem to suggest that the direction of causality runs from growth in electric energy consumption to GDP growth. Test results presented in Table 4 however suggest a unidirectional causal relationship between the two variables; with the direction of causality running from growth in GDP to growth in electric energy consumption.

The above result is significant in that, it provides the long awaited empirical evidence on the causal relationship between the two key variables in this emerging economy (causality as defined by Granger (1969)). This verified causal relationship could provide the information needed to formulate long term policies geared towards sustaining economic growth in this emerging economy. It could for instance, provide policy makers with a verifiable point of reference in making the case for finding long-term solution to the seasonal electric energy supply difficulties facing the economy. The study could further serve as the basis for making the case for the huge financial outlay required to overcome electric energy supply difficulties in the country. For instance, with this verified causal linkage, policy makers could make the case for continual infusion of resources and investment in the energy sector to help keep pace with ongoing growth in GDP; since growth in GDP granger causes growth in demand for electric energy. Additionally, the outcome could also inform strategic foreign direct investment drive programs, by stressing the importance of continual investment in dependable energy supply as a means of attracting investments and sustaining economic growth. This study further provides evidence which ties the economy's continual GDP growth prospect to sustained growth in energy supply.

With direction of causal relationship between economic growth and electric energy consumption identified, this study augment the Granger causality approach above with a test for the magnitude of the causal impact exerted by GDP growth on energy consumption (supply). Critics of the above causality approach often argue that knowing the exact direction of causal relationship between core economic indicators is crucial, but not enough to ensure effective planning and implementation of growth augmenting policy initiatives. Consequently, in addition to the identified direction of causal relationship between electric energy supply and growth in GDP, this section also measures the percentage growth in electric energy supply required to accommodate a percentage growth in GDP. If GDP growth granger causes growth in energy consumption, then it is critical that growth in energy consumption resulting from a percentage growth in GDP is quantified. Quantifying this induced growth in energy consumption is critical in planning for the required investments needed to keep pace with continual growth in GDP. This section, test for how a percentage growth in GDP impact variability in growth in energy consumption using simple OLS[d] regression as follows:

$$\mathcal{Y}_{\text{energyc}} = \beta_0 + \beta_1 \mathcal{X}_{\text{gdp}} + \varepsilon \tag{9}$$

Where $\mathcal{Y}$ = Energy Consumption growth and $\mathcal{X}$ = Gross Domestic growth

As expected, P-value of OLS regression results indicates growth in GDP is significant in explaining variability in energy consumption. However, the result also reveals another dimension of the relationship least addressed in most existing literature on causal relationship between the two variables. Granger causality test conducted above do not give any information about the percentage growth in electric energy consumption required to sustain current GDP growth trend; aside the direction of causal relationship. Augmenting the Granger causality test with this procedure which measures the magnitude of growth required in the energy sector provides a much clearer picture on the relationship between the two variables. OLS regression results show that a percentage growth in GDP in this emerging economy induces approximately 2% (1.98%) growth in energy consumption. This is significant, in that, it shows the magnitude of the causal relationship between the two variables. It further provides a framework for assessing the quantum of investment in the energy sector critical to sustain the economy on its current growth trajectory. In order words, to sustain the current average GDP growth rate of

[d] OLS regression results are rather discussed since only two variables are tested in a simple OLS model

between 3% and 6% annually, growth in energy generation must grow approximately between 6% and 12% respectively annually.

8 Conclusions

This paper makes an inquest into the dynamic relationship between electric energy consumption and growth in GDP in an emerging economy using data spanning a period of 39 years. Test for causal relationship is based on Sims (1972) test modeled on Granger's (1969) definition of causality. Result show that there exist a unidirectional causal relationship running from GDP growth to electric energy consumption; and a percentage growth in GDP induces approximately 2% growth in electric energy consumption all things being equal.

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Appendix

5.1 GDP Variable Unit Root Test : Table 1

Augmented Dickey-Fuller test for unit root No of obs = 122

	Interpolated Dickey-Fuller		
Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t) -16.195	-3.503	-2.889	-2.579

MacKinnon approximate p-value for Z(t) = 0.0000

5.2 Electric Energy Consumption Variable Unit Root Test: Table 2

Augmented Dickey-Fuller test for unit root No of obs = 122

	Interpolated Dickey-Fuller		
Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t) -76.798	-3.503	-2.889	-2.579

MacKinnon approximate p-value for Z(t) = 0.0000

Causality Summary Table 3

F- test	Causal relationships
If equ (5) holds but equ (8) does not hold	X causes Y
If equ (8) holds but equ (5) does not hold	Y causes X
If both equ (5) and equ (8) does not hold	Bidirectional relationship
If both equations hold	Y and X are independent

equ = equation

Table 4 Standard Granger Causality Test between Electric Energy Consumption and Economic Growth

Null Hypothesis	F-Statistic	P-value	Decision
EECG does not Granger cause GDPG	1.69(1)	0.1995	Fail to Reject
GDPG does not Granger cause EECG	97.09(1)	0.0001	Reject

*** EECG – Electric Energy Consumption Growth**
*** GDPG – Gross Domestic Product Growth**
*** Number of lags in parenthesis**