Are Energy Consumption and GDP Per Capita Asymmetric? Empirical Evidence from Nigeria

Olalekan Bashir Aworinde*

Abstract

The paper examines the causal relationship between energy consumption and GDP per capita in Nigeria. The kernel of this paper is the use of a newly developed asymmetric causality test of Hatemi-J (2012) that separates the causal impact of positive shocks from negative shocks. The results of standard symmetric causality tests show that there is no causal relationship between energy consumption and GDP per capita. However, the results of asymmetric causality tests show that positive shocks in GDP per capita cause positive shocks in energy consumption. This implies that if GDP per capita increases, then energy usage per capita will also increase. The implication of this result in Nigeria is that it is possible to implement energy conservation policies with little adverse or no effects on economic growth.

Key Words: Energy consumption, Asymmetric Causality, Nigeria
JEL Classification: Q43, C32

*Department of Economics, Tai Solarin University of Education, Nigeria & University of Bath, Bath, BA2 7AY, United Kingdom aworindeob@tasued.edu.ng, lekanawo2002@yahoo.com.

1 Introduction

The relationship between energy consumption and economic growth has been a topical discourse over the years. This has led to an empirical investigation into the relationship with authors using diverse model specifications and econometric approach, ranging from a bivariate to a multivariate model specification, as well as different time period. However, the results have been mixed, with studies supporting the four strands of assumptions, and each of which has its own implication.

First, a unidirectional causality from energy consumption to economic growth, this implies that energy saving policies may hinder growth, because such economy is dependent on energy to grow. Second, a unidirectional causality from economic growth to energy consumption, here energy saving policies may have little or no negative efects on growth. However, if the causal relationship from energy consumption to growth is positive, the adoption of energy saving policies can lead to decline in growth and employment. Conversely, if the causal relationship from to growth to energy consumption is negative, the use of energy saving policies can lead to increase in output.

Third, where there is no feedback causal relationship between energy consumption and economic growth, the adoption of a conservative energy policies will have no consequential effect on economic growth. Fourth, a bidirectional causal relationship between economic growth and energy consumption, suggest that they are jointly determined and interrelated. Thus, the adoption of energy saving policies will be detrimental to growth on one hand and on the other hand more energy utilization will result in a higher rate of growth.

The existing literature on the causal relationship between economic growth and energy consumption has, to date, focused mainly on symmetric cointegrating relationship, and has ignored the possibility of an asymmetric cointegrating relationship. This remains a major gap to be filled in the economic growth and energy consumption literature for Nigeria. The kernel of this paper is the use of a newly developed asymmetric causality test of Hatemi-J (2012) that separates the causal impact of positive shocks from negative shocks.

The remainder of the paper is organized as follows. Section 2 provides the theoretical linkages and the empirical evidence on the energy consumption and economic growth literature. Section 3 is devoted to the econometric methodology of Hatemi-J asymmetric causality test, while section 4 provides the description of data and results. Section 5 concludes.

2 Theory and Evidence

Generally there are four strands to the causal relationship between energy consumption and economic growth, all of which has important policy implications. First is the neutrality hypothesis, this hypothesis states that energy consumption and economic growth are not related. This implies that neither conservative nor expansive policies in relation to energy consumption have any effect on output. Thus, there is absence of causal relation between energy consumption and growth. Empirical evidence that validates this hypothesis are majorly from developed countries and this includes Akarca and Long (1980), Yu and Hwang (1984) Yu and Jin (1992) Cheng (1995), Chiou-Wei et al (2008), Payne (2009) for the US; Fatai et al., (2004) for New Zealand; Altinay and Karagol (2004), Jobert and Karanfil (2007), Halicioglu (2009), Soytas and Sari (2009), for Turkey; Yu and Choi (1985) for the UK; Erol and Yu (1988) for France. Similar results are found in Nigeria by Akinlo (2008) and Abalaba and Dada (2013); Masih and Masih (1996) for Malaysia and Soytas and Sari (2003) for India.

Second, the conservation hypothesis which maintains that the policy of conserving energy demand may be carried out with little or no damaging effect on economic growth for a less energy dependent economy. This hypothesis is supported if an increase in economic growth leads to an increase in energy consumption, thus the direction of causality is from economic growth to energy consumption. Empirical evidence in support of this view includes but not limited to Kraft and Kraft (1978), Abosedra and Baghestani (1989) for the US; Cheng (1999) for India; Chang and Wong (2001), Glasure and Lee (1997) for Singapore; Yu and Choi (1985), Soytas and Sari (2003) for South Korea; Cheng and Lai (1997) for Taiwan; Lise and Van Montfort (2007) for Turkey; Ang (2008) for Malaysia; Zhang and Cheng (2009) for China; and Hatemi-J and Irandoust (2005) for Sweden; Erol and Yu (1987) for Italy and Germany; Masih and Mashi (1996) for Indonesia; Wolde-Rufael (2005) for Algeria, Congo DR, Egypt, Ghana and Ivory Coast; Chiou-Wei et al. (2008) for Philippines and Singapore; Akinlo (2008) for Gambia, Ghana, Sudan, Zimbabwe, Congo and Senegal; Wolde-Rufael (2009) for Nigeria.

A third strand of causal relation between energy consumption and economic growth is the growth hypothesis. This hypothesis suggests that any restrictions on the use of energy may hamper growth, while energy increase are likely to enhance growth. Thus, energy consumption plays an important role in economic growth both directly and indirectly in the production process as a complement to labour and capital. The direction of causation is from energy consumption to economic growth. Studies in favour of this hypothesis includes Stern (1993, 2000), Bowden and Payne (2009) for the US ; Erol and Yu (1987) for Canada; Wolde-Rufael (2005) for Nigeria, Cameroon and Morocco; Shiu and Lam (2004) for China; Masih and Masih (1996) for India; Asafu-Adjaye (2000) for Indonesia; Yu and Choi (1985) for the Philippines; Morimoto and Hope (2004) for Sri Lanka; Yang (2000) for Taiwan; Soytas and Sari (2003), Altinay and Karagol (2005) for Turkey; Chiou-Wei et al. (2008) for Taiwan, Hong Kong, Malaysia, Indonesia.

The last strand of causal relation between energy consumption and economic growth is called the feedback hypothesis. This hypothesis suggests that energy consumption and economic growth are jointly determined and affected at the same time. Thus, there is a bi-directional or feedback causal relationship between energy utilization and output Empirical evidence in support of this includes; Ebohon (1996) for Nigeria, Masih and Mashi (1996) for Pakistan; Hwang and Gum (1991), Asafu-Adjaye (2000) for Philippines and Thailand; Glasure (2002) for Korea; Hondroyiannis et al. (2002) for Greece; Soytas and Sari (2003) for Argentina; Ghali and El-Sakka (2004) for Canada; Paul and Bhattacharya (2004) for India; Wolde-Rufael (2005) for Gabon and Zambia; Belloumi (2009) for Tunisia; Erol and Yu (1987) for Japan; Erdal et al. (2008) for Turkey; Lee (2006).

3 Methodology

This paper explores the asymmetric causality test propounded by Hatemi-J (2012). The uniqueness of this test is that it separates causal impact of positive shocks from negative shocks. It is a novel approach because economic agents respond differently to either good or bad news. Given that energy consumption, denoted by EC and the gross domestic product per capital, denoted by (GDP) are difference stationary, thus EC and GDP can be define as a random walk process of the form;

$$EC_t = EC_{t-1} + \varepsilon_{1t} = EC_0 + \sum_{i=1}^{t} \varepsilon_{1i} \tag{1}$$

and

$$GDP_t = GDP_{t-1} + \varepsilon_{2t} = GDP_0 + \sum_{i=1}^{t} \varepsilon_{2i} \tag{2}$$

where t =1, 2, ...,T. The initial values are the constant EC_0 and GDP_0, and the variables ε_{1t} and ε_{2t} represents the white noise error terms. Positive and negative shocks can be identified as the following respectively: $\varepsilon_{1i}^{+} = \max(\varepsilon_{1i}, 0)$, $\varepsilon_{2i}^{+} = \max(\varepsilon_{2i}, 0)$, $\varepsilon_{1i}^{-} = \min(\varepsilon_{1i}, 0)$ and $\varepsilon_{2i}^{-} = \min(\varepsilon_{2i}, 0)$. Thus, $\varepsilon_{1i} = \varepsilon_{1i}^{+} + \varepsilon_{1i}^{-}$ and $\varepsilon_{2i} = \varepsilon_{2i}^{+} + \varepsilon_{2i}^{-}$ is define as:

$$EC_t = EC_{t-1} + \varepsilon_{1t} = EC_0 + \sum_{i=1}^{t} \varepsilon_{1i}^{+} + \sum_{i=1}^{t} \varepsilon_{1i}^{-}$$

and also

$$GDP_t = GDP_{t-1} + \varepsilon_{2t} = GDP_0 + \sum_{i=1}^{t} \varepsilon_{2i}^{+} + \sum_{i=1}^{t} \varepsilon_{2i}^{-}$$

Lastly, the positive and negative shocks of each variable can be defined in a cumulative form as $EC_t^{+} = \Sigma_{i=1}^{+} \varepsilon_{1i}^{+}$, $EC_t^{-} = \Sigma_{i=1}^{-} \varepsilon_{1i}^{-}$, $GDP_t^{+} = \Sigma_{i=1}^{+} \varepsilon_{2i}^{+}$ and $GDP_t^{-} = \Sigma_{i=1}^{-} \varepsilon_{2i}^{-}$. The positive and negative components can be used to test for the asymmetric causality between the variables. For instance, if we are interested in testing for causality between the positive components of EC and GDP, then our data is defined as $y_t^{+} = (EC_t^{+}, GDP_t^{+})$, if our interest is to test for the negative components of EC and GDP, then the vector is defined as $y_t^{-} = (EC_t^{-}, GDP_t^{-})$. The test for causality can thus be implemented via the following vector autoregressive model with the length of the underlying dynamic equal to L, VAR(L):

$$y_t^{+} = \upsilon + A_1 y_{t-1}^{+} + ... + A_L y_{t-L}^{+} + u_t^{+}, \tag{3}$$

where y_t^{+} is the 2x1 vector of the variables, υ is the 2x1 intercept vector, and u_t^{+} is a 2x1 vector of error terms. The matrix A_r is a 2x2 matrix of parameters for lag order $r(r = 1, ..., L)$. Before conducting tests for causality it is expedient to select the optimal lag order L, which can be achieved through minimizing the Hatemi-J (2003) information criterion:

$$HJC = \ln(\left|\hat{\Omega}_f\right|) + f2^{-1}T^{-1}(m^2 \ln T + 2m^2 \ln(\ln T)), \qquad f = 0, ...L - \max. \tag{4}$$

where $\left|\hat{\Omega}_f\right|$ is the determinant of the variance–covariance matrix of the residuals in the VAR model based on lag length f, m is the number of equations in the multivariate model, and T is the sample size. After determining the optimal lag order, we test the following null hypothesis:

$$H_0: \text{ the row } j, \text{ column } k \text{ element in } A_r \text{ equals zero for } r = 1, ...L. \tag{5}$$

Before defining a Wald test for testing the above hypothesis there is the need to introduce some denotations. Therefore, let us define the following:

$Y := (y_1^{+}, ...y_T^{+})(m \text{ x } T)$ matrix,

$D := (\upsilon, A_1, ...A_p)(m \text{ x } (1 + mL))$ matrix,

$$Z_t := \begin{bmatrix} 1 \\ y_t^+ \\ y_{t-1}^+ \\ \vdots \\ y_{t-p+1}^+ \end{bmatrix} ((1+mL) \text{ x } 1) \text{ matrix, for } t = 1, ...T,$$

$Z := (Z_0, ..., Z_{T-1})((1+mL)$ x $T)$ matrix, and
$\delta := (u_1^+, ..., u_T^+)(m$ x $T)$ matrix.
Using the above denotations, the VAR(L) model is presented compactly as:

$$Y = DZ + \delta \tag{6}$$

The following Wald test is implemented to test the null hypothesis of non-Granger causality, $H_0 : R\beta = 0$:

$$\text{Wald} = (R\beta)'[R((Z'Z)^{-1} \otimes S_U)R']^{-1}(R\beta), \tag{7}$$

here $\beta = vec(D)$ and vec represents the column-stacking operator; $\otimes$ is the Kronecker product, and R is a L x $m(1+mL)$ indicator matrix consisting of ones for restricted parameters and zeros for the rest of the parameters. The variance–covariance matrix of the unrestricted model is defined as $S_U = (\hat{\delta}_U^{'}\hat{\delta}_U)/(T-q)$,where q represents the number of parameters in each of the equations in the estimated VAR system. Assuming that the assumption of normality of the error terms in the regression holds, the Wald test in Eq. (7) is asymptotically distributed as χ^2 with L degrees of freedom. However, if the data is not normally distributed and if ARCH effects prevail then the Wald test will not follow the assumed asymptotic distribution. This is especially the case when the sample size is small. It is widely agreed in the literature that bootstrap simulations can remedy this statistical problem. This technique can be performed as follows;

(1) Run the regression in model (6) with the imposed restrictions as implied by the null hypothesis of Granger noncausality.

(2) Generate the bootstrap data, Y_t^*,as $Y^* = \hat{D}Z + \delta^*$

Notably, the bootstrapped residuals(δ^*) are created by T independent random draws from the regression's modified residuals, which are mean-adjusted in each replication in order to ensure the mean value of the residuals is zero in each simulation sample. The original residuals of the regression are adjusted via leverages to retain constant variance.

(3)The bootstrap simulations are repeated 10,000 times, and each time the Wald test is estimated so as to generate the distribution of this test. Then, by taking the (α)th upper quantile of the distribution of the bootstrapped Wald test, the bootstrap critical value at the $\alpha-$level of significance, denoted by (c_α^*) is acquired.

(4)The final step is to calculate the Wald test based on the original data to the bootstrap critical value c_α^*. The null hypothesis of non-Granger causality is rejected at the α level of significance based on bootstrapping if the estimated Wald test is higher than the critical value c_α^*. All bootstrap simulations are performed by using statistical software components written in GAUSS by Hatemi-J (2011).

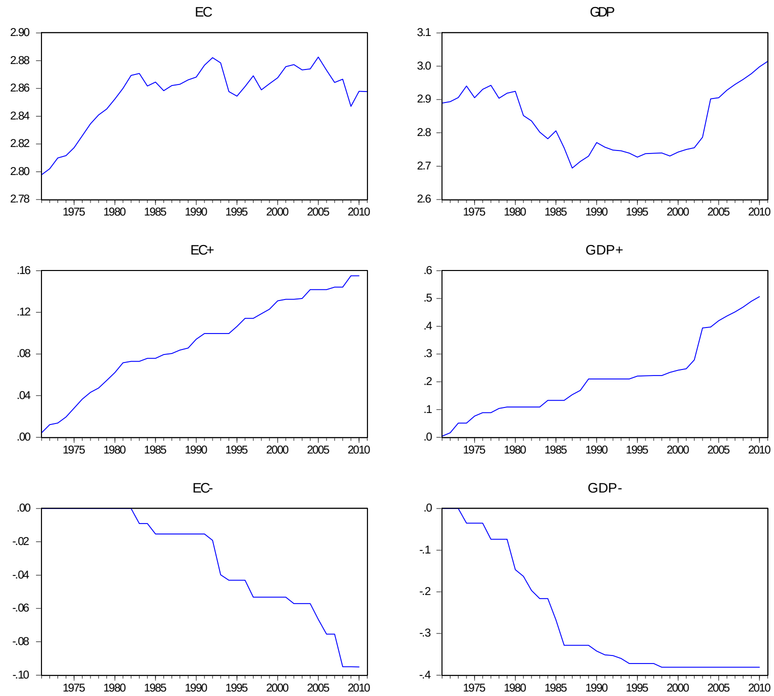

Fig. 1: The time plots of the variables as well as their positive and negative cumulative sums, for the period 1971-2010. EC is the logarithmic value of energy consumption per capita, GDP is the logarithmic value of gross domestic product per capita. The cumulative positive sum of each variable is indicated by + and the cumulative negative sum is indicated by -.

4 Data and Results

4.1 Data

The study used annual data on energy usage (kg of oil equivalent) per capita and real GDP per capita for Nigeria. The data is collected from the World Development Indicators (WDI), which are published by the World Bank. Our sample consists of 40 observations ranging from 1971 to 2010. Both variables are expressed in logarithmic form.

4.2 Results

The first step in our empirical analysis is conducting unit root tests. Using a battery of unit root tests there is overwhelming evidence that each of the is stationary in their first difference and this is show in Table 1. This is also evident from the time plots presented in Fig. 1. Following, Toda and Yamamoto (1995) we include an additional lag in the VAR model to account for one unit root. In addition, the study also conduct specification and diagnostic test and this is shown in Table 2. The optimal lag length is one for all the models. The null hypothesis of no MV-ARCH(1) and no serial correlation could not be rejected in both cases. However, the null of multivariate normality is rejected in all the three cases. Thus, it is important to make use of the bootstrap simulation method so as to achieve a reliable critical values for the causality tests.

The results of the symmetric and asymmetric causality tests are presented in Table 3. The symmetric causality tests show that there is no causal relationship between energy consumption and economic growth. This result is consistent with the study of Akinlo (2008) and Abalaba and Dada (2013) for Nigeria. Based on the asymmetric causality test, it is evident that only the null hypothesis that positive shocks in GDP do not Granger cause positive energy shocks can be rejected. The estimated causal parameter in this case is 0.985, this implies that a 1% permanent positive GDP shock will cause a 0.98% increase in energy shocks in Nigerian economy. The null hypothesis of no Granger causality cannot be rejected for the other seven cases that deal with both matching and opposite shocks.

5 Conclusion

This paper explores the possibility of a symmetric and asymmetric causal relationship between energy consumption and GDP per capital in Nigeria. Conducting a specification and diagnostic tests, results show that the data does not follow a normal distribution, thus, we employ the bootstrapping simulation method to provide accurate critical values. The results of standard symmetric causality tests show that there is no causal relationship between energy consumption and GDP per capita. However, the results of asymmetric causality tests that separate the causal impact of positive shocks from positive ones reveal that the null hypothesis of GDP per capita do not cause energy consumption can be rejected. Interestingly, if one only relied on the results of symmetric causality tests one would conclude that the neutrality hypothesis holds in Nigeria. However, this would be a misleading conclusion because the conducted asymmetric causality tests indicate clearly that positive shocks in GDP per capita cause positive shocks in energy consumption. This implies that if GDP per capita increases, then energy usage per capita will also increase. The implication of this result in Nigeria is that it is possible to implement energy conservation policies with little adverse or no effects on economic growth.

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Table 1: Unit Root Tests

Variable	*ADF*	*PP*	*NG*	*ADF*	*PP*	*NG*
	Series in Levels			Series in first differences		
EC	-1.895	-1.762	-2.700	-5.661***	-5.659***	-19.319***
GDP	-0.028	-0.048	-0.742	-5.182***	-5.289***	-19.012***
EC^{+}	-2.307	−2.681	-3.388	-5.563***	-5.543***	-18.148***
EC^{-}	-1.897	-1.877	-4.010	-6.051***	-6.050***	-18.939***
GDP^{+}	-0.766	-0.942	-2.893	-5.421***	-5.432***	-18.806***
GDP^{-}	-0.275	-0.234	-1.429	-5.177***	-5.295***	-18.237***

Note: ADF, PP and NP denote the Augmented Dickey-Fuller unit root test, the Phillips-Perron unit root test and the Ng-Perron unit root test respectively.
*****,** and *** indicate level of significance at 10, 5 and 1 per cent respectively.

EC represents for energy consumption and GDP is the GDP per capita. Cumulative sums of positive and negative shocks are indicated by + and - signs respectively.

Table 2: Specification and Diagnostic Test for the VAR Model

Variables	VAR Order[a]	Normality[b]	MV-ARCH[c]	Autocorrelation[d]
EC, GDP	1	0.000	0.928	0.924
EC^{+},GDP^{+}	1	0.000	0.667	0.613
EC^{-},GDP^{-}	1	0.000	0.719	0.361

Note: Note: a The VAR order is chosen on the basis of the information criteria and on the basis of speci.cation tests.
bThe Doornik and Hansen (2008) statistic is applied to test the null hypothesis of multivariate normality.
c A test provided by Hacker and Hatemi-J (2005) was implemented for the multivariate ARCH effects. The simulations of this ARCH test were conducted by a statistical software component produced by Hacker and Hatemi-J (2009).
d Multivariate autocorrelation LM test. For the null hypothesis of no serial correlation (of order 1) the test statistic has an asymptotic chi-square distribution.

EC represents energy consumption and GDP is the GDP per capita. Cumulative sums of positive and negative shocks are indicated by + and - signs respectively.

Table 3: Causality test using bootstrap simulation technique

Null hypothesis	Test Value	Bootstrap CV at 1%	Bootstrap CV at 5%	Bootstrap CV at 10%	Optimal lag
Panel A: Symmetric Causality Test					
EC$\nRightarrow$ GDP	0.125	7.364	4.189	2.887	1
GDP$\nRightarrow$ EC	0.320	8.090	4.180	2.903	1
Panel B: Asymmetric Causality Test					
$EC^{+} \nRightarrow GDP^{+}$	0.366	7.460	4.232	2.864	1
$GDP^{+} \nRightarrow EC^{+}$	4.211	8.075	4.141	2.788	1
$EC^{-} \nRightarrow GDP^{-}$	0.200	8.637	4.298	2.746	1
$GDP^{-} \nRightarrow EC^{-}$	0.166	8.428	4.001	2.714	1
$EC^{+} \nRightarrow GDP^{-}$	0.349	7.550	4.338	2.975	1
$GDP^{-} \nRightarrow EC^{+}$	0.613	8.615	4.639	3.136	1
$EC^{-} \nRightarrow GDP^{+}$	0.183	9.584	4.409	2.656	1
$GDP^{+} \nRightarrow EC^{-}$	0.793	11.500	4.829	2.721	1

Notes: The symbol EC$\nRightarrow$GDP means that EC does not cause GDP.

CV means critical value.