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Energy Consumption and Economic Growth in Nigeria: A Bounds Testing Cointegration Approach

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Abstract: This study investigates the relationship that exists between energy consumption and economic growth using Nigerian annual time series from 1970-2005. The non-causality approach to causality testing and the bounds testing approach to cointegration, which is based on Autoregressive Distributed Lag (ARDL) procedure proposed are employed. In this study, energy consumption is further disaggrigated into oil, gas and electricity consumption in order to present more robust analysis. The findings from this study, reveal a unidirectional causal relationship between total energy consumption and economic growth running from total energy consumption to economic growth. This is also true in the case of oil consumption and economic growth with the direction of causality running from oil consumption. Gas consumption causes growth with no feedback. The study also shows that there is no causal relationship between electricity consumption and economic growth in either direction. The cointegration test identifies long run relationships between total energy consumption and economic growth and also between oil consunption and economic growth. Meanwhile, the cointegration analysis reveals no long run relationship between gas consumption and economic growth and also between electricity consumption and economic growth.

Key words: Energy consumption, economic growth, causality, cointegration, bounds testing, ARDL

INTRODUCTION

The relationship that exists between energy consumption and economic growth has been of great interest to many researchers. The empirical argument has been centered on whether economic growth responds to increase in energy comsumption or whether increase in economic growth actually propel increased energy consumption. To this end, various empirical studies have explored the causal and long run relationships that exist between these 2 variables. So far, there have been different and sometime conflicting empirical findings as regards this relationship in different economies. While, some findings reveal a causal relationship (either unidirectional or bi-directional) between energy consumption and economic growth, others are of the opinion that there exists no causal relationship at all in any direction between the variables, thus supporting the neutrality hypothesis.

It should be noted, that the findings of these empirical studies have different policy implications. For instance, if a unidirectional causal relationship is established running from energy consumption to economic growth, policy aimed at reducing energy consumption would have adverse effect on the economic growth, while any policy geared towards increasing the rate of energy consumption would have recorded a positive impact on the economic growth. On the other hand, the economic growth rate would be unaffected if, say, energy tax rate is increased provided a causal relationship is affirmed running from economic growth to energy consumption. This means that as the income of a nation increases, their energy consumption increases as well. Again, where a bi-directional causal relationship exists, then there is a feedback interaction between energy consumption and economic growth. Meanwhile, under a neutrality hypothesis, the impact of policy aimed at any of the variable, say, energy consumption is not transferred to economic growth.

Why the need to properly investigate the relationship between energy consumption and economic growth in Nigeria? Nigeria as the largest oil producer in the Sub-Saharan Africa and the 5th largest petroleum exporting country in the Organization of Petroleum Exporting Countries (OPEC) is faced with the challenge of economic growth. From 1995-2005, the average annual growth rate amounts to about 4.6%. Presently, the government of Nigeria is taking a conscious step towards moving the economy from its deplorable condition to a better state. Nigeria is planning and working towards becoming one of the 20th largest economies in the world by the year 2020. Apart from the various economic, financial and social

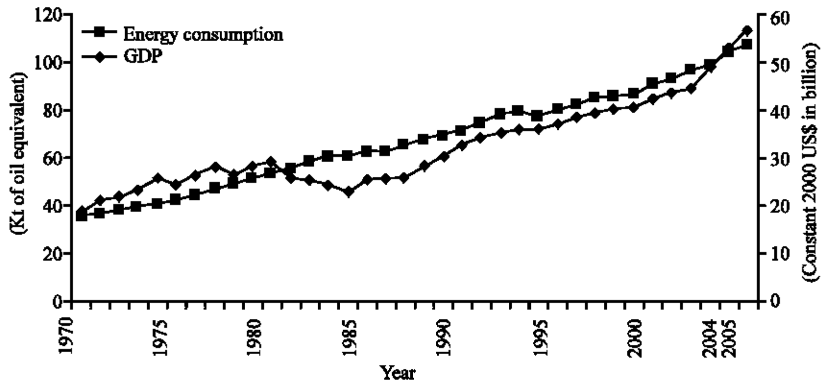

Fig. 1: Energy consumption and economic growth trend in Nigeria (1970-2005). Source: World Development Indicator (2007)

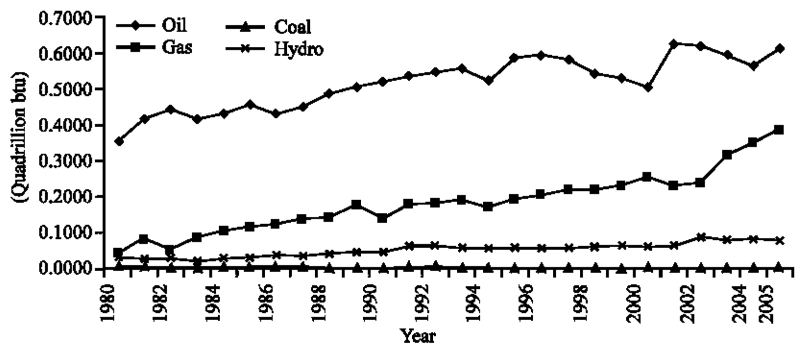

Fig. 2: Nigerian energy consumption mixed (1980-2005). Source: Energy Information Administration (EIA) (2005)

reform initiatives being embarked upon by the government of Nigeria, great attention has been focused on the energy sector of the economy.

From Fig. 1, the relationship between economic growth (GDP) and energy consumption is dipicted. The figure reveals an upward trend both in GDP and energy consumption from 1970-2005. Except from 1981-1984, where a decreasing trend in GDP is noted, energy consumption and GDP display a high positive correlation from 1985-2005. Again, energy consumption situation in Nigeria in Fig. 2. Figure 2 reveals trend in energy consumption mix from 1980-2005. Oil consumption followed by gas consumption obviously dominate energy consumption mix in Nigeria from 1970-2005. For instance, in 2005 energy consumption mix for Nigeria is dominated by oil, which accounts for about 57%, followed by natural gas, which accounts for about 36% and hydroelectricity (7%). Other energy sources such as coal, nuclear and renewables are currently not part of the country's energy consumption mix. From 1980-2005, the share of oil in energy mix has decreased from 82-56%. Natural gas consumption increased from 9-35%. Hydroelectricity has seen a small increase from 6.6 about 7%.

Premised on the assumption that energy consumption is a sine qua non to economic growth, the stakeholders have identified the need for energy infrastructural development with the sole aim of increasing energy consumption through energy service availability, accessibility and affordability in Nigeria thus, enhancing the economic potential of the people. Therefore, as income per capita increases and living standards also improve, per capita energy consumption is expected to increase and this eventually necessitates an increase in energy infrastructures. Therefore, this study is motivated based on this development. It is therefore, necessary to re-evaluate the relationship that exists between the energy consumption and economic growth in Nigeria.

Following the seminar research of Kraft and Kraft (1978), where they investigated the causal relationship between economic growth and energy consumption for the period of 1947-1974 in the case of the United States, there have been several other empirical studies carried out to examine the relationship between energy consumption and economic growth both in the developed and developing countries, with, as earlier noted, different findings been established (Fatai *et al*., 2004; Ghali and

El-Sakka, 2004; Masih and Masih, 1997; Lee, 2005; Glasure, 2002). Meanwhile, factors such as differences in the data definition and measurement technique, time frame and the methodological approaches employed in various empirical studies could be responsible for the conflicting findings as regards energy consumption and economic growth relationship.

There are a number of methodological issues arising from the investigation of energy consumption and economic growth relationship. For instance, econometric methodologies such as single equation Ordinary Least Square (OLS), Engle and Granger (1987), Johansen (1988) and Johansen and Juselius (1990) cointegration procedures have been widely used in investigating the relationship between energy consumption and economic growth. Of course, the application of these methodologies is not without various limitations. For instance, the use of traditional Granger causality test becomes insufficient in a situation where the time series are I (1) and cointegrated (Toda and Yamamoto, 1995; Zapata and Rambaldi, 1997). Again, the application of Johansen (1988) cointegration technique presupposes that the underlining regressors are all integrated of order one, otherwise, the standard statistical inference based on the conventional likelihood ratio tests becomes invalid and could also lead to erroneous inferences (Pesaran *et al*., 2001; Harris, 1995; De Vita *et al*., 2005). Again, the use of several variables can help avoid econometric problems caused by a potential omitted variable bias and offers multiple causality channels which, under a bivariate approach, may remain hidden or can lead to spurious correlations and thereby to erroneous conclusions (Lütkepohl, 1982; Stern, 1993).

The objectives of this study are clear. Firstly, the study aims at re-evaluating energy consumption and growth relationship by employing more robust econometric methodologies. The Toda and Yamamoto (1995) non-causality test and the bounds testing cointegration estimation technique proposed by Pesaran *et al.* (2001), which is based on the Auto-Regressive Distributive Lag (ARDL) and the Unrestricted Error Correction Model (UECM) are used for the case of Nigeria. Secondly, to enrich the study, the energy consumption is further disaggregated into oil, gas and electricity consumption with the aim of outlining appropriate policies regarding each component.

MATERIALS AND METHODS

Study scope and data definition: In an attempt to investigate, the relationship between energy consumption and economic growth, this study shall employ the Nigerian annual time series from 1970-2006. The time series data used in this study, include the per capita values of Total Energy Consumption (TEC), Oil Consumption (OIL), Gas consumption (GAS), Electricity Consumption (ELEC) and gross domestic product (Y). Consumer Price Index (CPI) is used to deflate the variables in order to arrive at their real forms. These variables are finally expressed in natural logarithm. They are sourced from the Central Bank of Nigeria Statistical Bulletin 2005, the National Bureau of Statistic (NBS), World Bank World Development Indicators (WDI) CD-Rom (2007) and Energy Information Administration (EIA) 2005.

In order to investigate the relationship that exists between the energy consumption and growth, this study follows the following procedures.

Firstly, the stationarity properties of the time series data used are examined with the aim of determining their order of integration. Thus, the unit root tests are carried out by employing the Ng and Perron (2001) Modified Unit Root tests. The aim here is to determine the underlying properties of the process that generate the presents the result and discussion of the anlaysis, while conclusion is presented in study time series variables employed. The choice of the Ng and Perron (2001) modified unit root test is based on the fact that the tests are more suitable for small samples than the traditional tests. Again, the null hypothesis of a unit root is not over-rejected when Ng and Perron (2001), modified unit root tests are employed (Sinha, 2007).

Secondly, the causal relationship between energy consumption and economic growth is examined by carrying out the non-causality test of Toda and Yamamoto (1995). This test does not require prior knowledge of the cointegration nature of the system and also the usual lag selection procedure can still be applied in a situation where the stability and rank conditions are not satisfied (Zapata and Rambaldi, 1997). In this study, the approach of Rambaldi and Doran (1996) shall be followed. Toda and Yamamoto (1995) non causality test employs a VAR model in the levels and augments the appropriate VAR order k by dmax, which is the maximum order of integration suspected to occur in the system. As a result of this, a VAR (k + dmax) has to be estimated in order to use the wald test for linear restrictions on the parameters of a VAR (k), which has an asymptotic chi-squared (χ^2) distribution. The Akaike Information Criteria is used to determine the lag structure of the VAR system, k. The following VAR system of equations is therefore, estimated:

$$\begin{aligned}\ln EC_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} \ln EC_{t-i} + \sum_{j=k+1}^{d} \alpha_{2i} \ln EC_{t-i} \\ + \sum_{i=1}^{k} \beta_{1i} \ln Y_{t-i} + \sum_{j=k+1}^{d} \beta_{2i} \ln Y_{t-i} + \mu_{1t}\end{aligned} \quad (1)$$

$$\ln Y_t = \eta_0 + \sum_{i=1}^{k}\eta_{1i}\ln Y_{t-i} + \sum_{j=k+1}^{d}\eta_{2i}\ln Y_{t-i} + \sum_{i=1}^{k}\delta_{1i}\ln EC_{t-i} + \sum_{j=k+1}^{d}\delta_{2i}\ln EC_{t-i} + \mu_{2t} \quad (2)$$

From Eq. 1 and 2, EC and Y represent the natural logarithms of Energy Consumption (for cases of total energy, oil, gas and electricity consumption) and economic growth, respectively, while d represents the maximum order of integration and k, the appropriate VAR order in the system. These equations are estimated by Seemingly Unrelated Regression (SUR) method. In Eq. 1, the null hypothesis is that economic growth, (Y), does not Granger-cause Energy Consumption (EC), while the null hypothesis in Eq. 2 states that energy consumption does not Granger-cause growth. Therefore, the condition for testing the null hypothesis for each of the equation must hold such that:

Ho: $\beta_{1i} = \beta_{2i} = 0$ (for Eq. 1)

and

Ho: $\delta_{1i} = \delta_{2i} = 0$ (for Eq. 2)

These hull hypotheses are tested against the alternative hypotheses, which can be specified for the 2 equations as:

H_1: $\beta_{1i} \neq 0$, $\beta_{2i} \neq 0$ (for Eq. 1)

and

H_1: $\delta_{1i} \neq 0$, $\delta_{2i} \neq 0$ (for Eq. 2)

It should be noted that i = 1, 2, ….. (k + d).

Lastly, having ascertained the direction of causality, this study shall proceed unto testing the long run (cointegration) relationship between the variables by employing the cointegration approach of Pesaran *et al.* (2001). Pesaran *et al.* (2001), proposed an Autoregressive Distributed Lag (ARDL) bounds testing approach to investigating the existence of cointegration relationship among variables. Compared to other contegration procedures, such as Engle and Granger (1987) and Johansen and Juselius (1990), the bounds testing approach appeared to have gained popularity in recent times due to the following factors: Both long-and short-run parameters of the specified model can be estimated simultaneously, the econometric burden of testing the order of integration among variables are avoided. This implies that the bounds testing approach is applicable irrespective of the order of integration whether the variables under consideration are purely I (0), purely I (1) or fractionally integrated and finally and the approach is also suitable for small samples. These reasons, therefore, make the technique a more robust and simple cointegration procedure. In this study, two specifications are considered since the long run relationship is intended to be normalized on both energy consumption and economic growth. The (ARDL) bounds testing equations are specified:

$$\Delta \ln EC_t = \alpha_0 + \alpha_1 \ln EC_{t-i} + \alpha_2 \ln Y_{t-1} + \sum_{i=1}^{q}\alpha_{3i}\Delta \ln EC_{t-i} + \sum_{i=1}^{p}\alpha_{4i}\Delta Y_{t-i} + \mu_{1t} \quad (3)$$

$$\Delta \ln Y_t = \eta_0 + \eta_1 \ln EC_{t-1} + \eta_2 \ln Y_{t-1} + \sum_{i=1}^{q}\eta_{3i}\Delta \ln EC_{t-i} + \sum_{i=1}^{p}\eta_{4i}\Delta Y_{t-i} + \mu_{2t} \quad (4)$$

From Eq. 3 and 4, Δ represents the difference notation, while lnEC and lnY remain as earlier defined. The null hypothesis for each of the equations is:

$H_{0:}$ $\alpha_1 = \alpha_2 = 0$

This is tested against the alternative hypothesis

H_0: $\alpha_1 \neq \alpha_2 \neq 0$

Meanwhile, the null hypothesis of the (ARDL) bounds testing is tested by considering Eq. 3 and 4 without the inclusion of the lagged variables ΔlnEC and ΔlnY based on the F-statistic. The computed F-statistic is then compared to the non-standard critical bounds values reported in Pesaran *et al.* (2001). If the computed F-statistic exceeds the critical upper bounds value, then the null hypothesis of no cointegration is rejected. If the computed F-statistic falls below the critical lower bounds value, then the null hypothesis of no cointegration is not rejected. But when the computed F-statistic falls between the critical lower and upper bounds values, then the knowledge of integration of the variables of under consideration is required, or else, no conclusion can be reached about cointegration status.

RESULTS AND DISCUSSION

Table 1 presents the results of Ng and Perron (2001) modified unit root tests. The variables under consideration appear to be I (1), which then means that the variables are stationary at first difference. Meanwhile, the essence of testing for the stationarity properties of the variables is because the (ARDL) bounds testing approach to cointegration becomes applicable only in the presence of a I (0) or I (1) variables. Thus, the assumption of bounds testing will collapse in the presence of I (2) variable. The result therefore, implies that the bounds testing approach is applicable in this study since, the variables are stationary at first difference that is I (1).

Table 1: Ng and Perron (2001) modified unit root tests

Variables	$Mz^d\alpha$	MZ^d_t	MSB^d	Mp^d_T
ΔInTEC	-14.3063**	-2.66568**	0.18633*	1.74617**
1%	(-13.8000)	(-2.58000)	(0.17400)	(1.78000)
5%	(-8.10000)	(-1.98000)	(0.23300)	(3.17000)
10%	(-5.70000)	(-1.62000)	(0.27500)	(4.45000)
ΔInOIL	-21.8600**	-3.26849**	0.14952**	1.24909**
1%	(-13.8000)	(-2.58000)	(0.17400)	(1.78000)
5%	(-8.10000)	(-1.98000)	(0.23300)	(3.17000)
10%	(-5.70000)	(-1.62000)	(0.27500)	(4.45000)
ΔlnELEC	-16.4308**	-2.86059**	0.17210**	1.51204**
1%	(-2.58000)	(-2.58000)	(0.17400)	(1.78000)
5%	(-1.98000)	(-1.98000)	(0.23300)	(3.17000)
10%	(-1.62000)	(-1.62000)	(0.27500)	(4.45000)
ΔlnGAS	-18.3855**	-2.37421*	0.19265*	1.93018*
1%	(-2.58000)	(-2.58000)	(0.17400)	(1.78000)
5%	(-1.98000)	(-1.98000)	(0.23300)	(3.17000)
10%	(-1.62000)	(-1.62000)	(0.27500)	(4.45000)
ΔInY	-10.0889**	-2.23464*	0.22150*	2.47246*
1%	(-2.58000)	(-2.58000)	(0.17400)	(1.78000)
5%	(-1.98000)	(-1.98000)	(0.23300)	(3.17000)
10%	(-1.62000)	(-1.62000)	(0.27500)	(4.45000)

The variables are expressed in their natural logarithms; while Δ symbolizes that the variables are in their first difference; The asymptotic critical values of Ng and Perron (2001) modified unit root tests are in brackets in their respective levels of significance; **(*) denotes the rejection of the null hypothesis at 1 (5%) significance level

To investigate the causal relationship in the case of energy consumption and economic growth in Nigeria, this study employs the Toda and Yamamoto (1995) non-causality test. As presented in Table 2, the results indicate that the causal relationship between total energy consumption and economic growth is unidirectional running from total energy consumption to economic growth. Moreover, oil consumption causes economic growth without a feedback causal relationship from economic growth. The same result is found in the case of gas consumption and economic growth. On the other hand, Toda and Yamamoto (1995) non-causality test reveals that there is no causal relationship between electricity consumption and economic growth as 'neutrality hypothesis' could be observed between the 2 variables.

Following the results of Toda and Yamamoto (1999) non-causality test (Table 2), different policy implications could be deduced for energy consumption and economic growth in Nigeria. Firstly, based on the fact that Nigeria is a net oil-exporting developing country whose growth heavily depends on the performance of the energy (oil) sector, energy consumption is therefore, expected to play a dominant role in the economic activity, thus, energy conservation policy could be detrimental to growth. On the other hand, energy efficiency through clean technology mechanism could be encouraged with minimal adverse impact on growth.

The result of Bounds testing cointegration further elucidates the relationship between energy consumption and growth in Nigeria as already revealed in the causality test (Table 3). A vector of variables integrated of order one is cointegrated if there exists linear combination of the variables, which are stationary. The idea behind cointegration is that if 2 or more time series move together in the long run, even though the series themselves are trended, the difference between them is constant. The result therefore, reveals that there exists a long run (cointegration) relationship between total energy consumption and economic growth. Long run relationships is also identified involving oil consumption and economic growth. Meanwhile, the result does not identify any long run relationship between electricity consumption and economic growth and also gas consumption and economic growth.

Table 2: Toda and Yamamoto (1995) non-causality test result

Null hypothesis	(k + d)	Wald statistics	Probability value	Sum of lagged coefficients
lnTEC does not cause lnY	2	12.18389*	0.0023	0.8386
lnY does not cause lnTEC	2	2.433689	0.2962	0.9438
lnOIL does not cause lnY	2	4.072679*	0.0248	0.5449
lnY does not cause lnOIL	2	0.357362	0.8364	0.1928
lnELEC does not cause lnY	2	1.755021	0.4158	0.0579
lnY does not cause lnELEC	2	0.915447	0.6327	0.4295
lnGAS does not cause lnY	2	6.856810*	0.0188	0.3961
lnY does not cause lnGAS	2	1.276913	0.3107	0.0134

* Indicates the rejection of null hypothesis 1 (5%) significance level

Table 3: Bounds testing cointegration result

Variables examined	Lags	F-statistic	Probability	Outcome
InTEC, lnY	1	5.969*	0.0133	Cointegration
lnOIL, lnY	1	5.809*	0.0120	Cointegration
lnELEC, lnY	1	3.911	0.2322	No cointegration
lnGAS, lnY	1	2.847	0.2701	No cointegration

The asymptotic critical value bounds are obtained from Table C1 (iii) case III: Unrestricted intercept and no trend for k = 1; Lower bound I (0) = 4.94 and upper bound I (1) = 5.73 at 5% significance level, while at the 1% significance level lower bound I (0) = 6.84 and upper bound I (1) = 7.84 (Pesaran *et al*., 2001); The lag structure was selected based on the Akaike Information Criterion; * Denotes the rejection of the null hypothesis at 1 (5%) significance level

CONCLUSION

The causal and long run relationship between energy consumption and economic growth is investigated in the case of Nigeria. Apart from the total energy consumption, this study further examines the relationship between disaggregated energy (oil, gas and electricity) consumption and economic growth. The annual time series from 1970-2006 is used. In order to properly explore, the energy-economy nexus in Nigeria, more robust econometric methodological approaches are utilized in this study. The approach of Toda and Yamamoto (1995) to causality testing and that of (ARDL) bounds testing cointegration procedure proposed by Pesaran *et al.* (2001) are employed.

In order to determine, the underlying properties of the process that generate the time series variables employed in this research that is, whether the variables in the model were stationary or non-stationary, the approach of Ng and Perron (2001) modified unit root test is used. The result reveals that the time series under consideration are stationary at first difference. This implies that the null hypothesis of 2 unit roots is rejected for all variables. The need for unit root test in this study is hinged on the fact that the bounds testing approach of Pesaran *et al.* (2001) is only applicable, where the variables are either I (0) or I (1).

While, total energy consumption, oil consumption and gas consumption are found to have unidirectional relationship with economic growth without feedback effect from economic growth, on the other hand, the study identifies no causal relationship between electricity consumption and economic growth. Furthermore, based on the bounds testing cointegration test, the study shows there is long run relationship between total energy consumption and economic growth and also between oil consumption and economic growth. On the other hand, the null hypothesis of no cointegration is accepted between gas consumption and econmic growth and also electricity consumption and economic growth.

In conclusion, the policy implication as evidenced in this study suggests that any policy aimed at increasing the per capita consumption of energy especially oil and gas would have a beneficial effect on economic growth. Therefore, in other to actualize its vision of becoming one of the 20th largest economies in the world by the year 2020, the Nigerian government should ensure massive investment in the energy sector especially energy infrastructural development with the aim of increasing energy consumption through energy service availability, accessibility and affordability. Nevertheless, it should be noted tha the findings from this study could still be augmented by employing different other methodologies that can acommodate investigating all the potential channels by which energy consumption and economic growth interact.

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