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Electricity Supply, Fossil fuel Consumption, Co_2 Emissions and Economic Growth: Implications and Policy Options for Sustainable Development in Nigeria

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ABSTRACT: This paper investigates the causal relationship among electricity supply, fossil fuel consumption, CO_2 emissions and economic growth in Nigeria for the period 1971-2009, in a multivariate framework.Using the bound test approach to cointegration, we found a short-run as well as a long-run relationship among the variables with a positive and statistically significant relationship between CO_2 emissions and fossil fuel consumption. The findings also indicate that economic growth is associated with increased CO_2 emissions while a positive relationship exists between electricity supply and CO_2 emissions revealing the poor nature of electricity supply in Nigeria. Further, the Granger causality test results indicate that electricity supply has not impacted significantly on economic growth in Nigeria. The results also strongly imply that policies aimed at reducing carbon emissions in Nigeria will not impede economic growth. The paper therefore concludes that a holistic energy planning and investment in energy infrastructure is needed to drive economic growth. In the long-run however, it is possible to meet the energy needs of the country, ensure sustainable development and at the same time reduce CO_2 emissions by developing alternatives to fossil fuel consumption, the main source of CO_2 emissions.

Keywords: CO_2 emissions; Economic growth; Electricity supply; Granger causality; Bounds testing; Fossil fuel consumption.
JEL Classification: Q41; Q42; Q43

1. Introduction

The inter-relationships between energy consumption and economic growth, as well as economic growth and carbon emissions have been the topic of intense research over the past few decades. Energy production and consumption are the major pillars of any viable economy as well as the major factors for socio-economic development and for the attainment of higher standards of living. It is therefore imperative to ensure that the production and consumption of energy are efficiently undertaken and mostly based on sustainable technologies which will be tolerated in the future.

Nigeria's electricity market, dominated on the supply side by the government-owned Power Holding Company of Nigeria (PHCN) has been incapable of providing minimum acceptable international standards of electricity service reliability, accessibility and availability for the past three decades. Cross-country comparison of electricity consumption indicates that Nigeria has one of the lowest per-capita electricity consumption (Table 1).To compensate for the power deficit, the domestic, commercial and industrial sectors persistently use private operational generators resulting in the burning of petroleum fuels. ECN (2009) indicates that an estimated 60 million Nigerians now own power generating sets for their electricity, while the same number of people spend a staggering N1.56 trillion ($13.35m) to fuel them annually. Following the recent increase in the cost of petroleum fuel and the constant breakdown of inferior generating sets, the amount spent by Nigerians to provide alternative source of power is really alarming. This ugly scenario has resulted in the high cost of doing business in Nigeria as well as increase in CO_2 emissions, the main culprit of global warming and climate change (Nnaji et al, 2012).

Table 1. Country Statistics of Electricity Generation and Per Capita Consumption

Continent	Country	Population (Million)	Generation Capacity (MW)	Per-Capita Consumption (kW)
North America	U.S.A	250	813,000	3.2
South America	Cuba	10.54	4,000	0.38
Europe (Central)	United Kingdom	57.5	76,000	1.1
Europe (Eastern)	Ukraine	49	54,000	1.33
Middle East	Iraq	23.6	10,000	0.42
Far East	South Korea	47	52,000	1.10
Africa	**Nigeria***	**140**	**<4000**	**0.03**
	Egypt	67.9	18000	0.27
	South Africa	44.3	45000	1.02

Source: Okafor et al., (2010)

An assessment of the existing literature on energy-economy-environment link over the past two decades indicates that most studies focused on the nexus of energy-economy or environment-economy with controversial and inconclusive results.

Recently, there are plethora of emerging empirical works which seek to integrate or incorporate both nexuses (energy-economy and environment-economy) in a multivariate framework for different economies (Ziramba (2013); Ali and Ozturk (2012); Ahmad et al (2012); Masuduzzaman (2012); Shahbaz et al, (2012); Shaari et al (2012); Qazi et al, (2012); Stern (2012); Saeki and Hossain (2011); Binh 2011;Tiwari (2011); Ahamad and Islam (2011); Noor and Siddiqi (2010); Alam, and Sarker (2010); Payne (2010); Ozturk (2010); Halicioglu (2008); Ang (2007); (2008); Apergis and Payne, (2009); Soytas et al., (2007); Chebbi and Boujelbene, (2008); Menyah and Wolde-Rufael, (2010))).

Most studies in Nigeria which examined the energy-environment-economy linkage focused on the total energy consumption, carbon emissions and Gross Domestic Product (GDP) growth with a few focusing on the relationship between electricity and aggregate growth but with mixed results. Meanwhile apart from electricity, fossil energy is an important component in the country's energy consumption. The importance of fossil energy can be acknowledged by the huge amount of money realized from the sale of crude oil and how an increase in petroleum price has adversely affected the domestic sector and the smooth operation of many businesses in the country.

The purpose of this paper is to empirically investigate the dynamic causal and long run relationship among disaggregated energy (electricity supply and fossil fuel), carbon emissions and economic growth in Nigeria for the period 1971-2009. It is expected that by decomposing energy (electricity and fossil) in the analysis, one can get a better picture of the causal relationship and the specific impact of the variables on economic growth. The direction of causality among the variables has significant policy implications. For instance if there is a uni-directional causality from electricity supply to economic growth, then growth hypothesis is supported, this would imply that electricity consumption has significant influence on economic growth directly. Thus policies that reduce electricity supply can have adverse impact on economic growth. If there is unidirectional causality from economic growth to electricity supply, then conservation hypothesis is supported and policies that reduce electricity supply will not have adverse impact on economic growth. Evidence of bidirectional causality between electricity supply and economic growth supports feedback hypothesis. In this case, policies that reduce electricity supply shall adversely affect economic growth and these economic fluctuations shall be transmitted back to electricity supply. Finally, if there is no causality between electricity supply and economic growth, then this implies that electricity conservation policies will not affect economic growth. In this study, we estimate a vector error correction model (VECM) based Granger non-causality test to test for the causal relationship. Next, we employ bound testing procedure to test if there is cointegrating relationship between the variables. The advantage of bound testing procedure is that, it can be applied without knowing the stationary properties of the variables. Thus it, spares us from pre-testing for unit roots. Moreover, bounds testing procedure is well suited to small data size.

2. Methodology and Data

2.1 Data description and Analytical Technique

The bound test approach to cointegration which is based on **Autoregressive Distributed lag (ARDL)** procedure proposed by Pesaran et al (2001), hereafter PSS, is used in the study to examine the relationship between economic growth, fossil fuel consumption, carbon emissions and electricity supply in Nigeria The study covers the periods of 1971 to 2009 by relying on annual time series data for Nigeria which are mainly from the World Bank country data base (2010), Carbon Dioxide Information Analysis Center, USA, and the Central Bank of Nigeria Statistical Bulletin of 2008, 2009 and 2010. The variables used are electricity supply (proxied by electricity consumption) (E_t), and fossil fuel consumption (F_t) as components of disaggregated energy use. The fossil fuel is made of coal, oil, petroleum and natural gas. Others are real GDP [(Y_t) proxy for economic growth] and total carbon dioxide emissions [(CE_t)] measured in million metric tons. All data are converted into natural logarithm. E-views 5.0 and Microfit 4.1 econometrics softwares were used for the analysis.

2.2 Time series properties of data

It is important to investigate the time series characteristics of the variables. The purpose is to determine the order of integration because the (ARDL) bounds testing approach to cointegration becomes applicable only in the presence of I(0) or I(1) variables, that is, being stationary/integrated at the level form or at first difference. Thus, the assumption of bounds testing will collapse in the presence of I(2) variable (Fosu et al., 2006). We conduct unit root tests on the variables included in the regression by employing both the Augmented Dickey-Fuller (ADF) and Phillips-Peron (PP) tests at 1%, 5% and 10% levels of significance. The null hypothesis is that unit root problem exists, that is, $\alpha 1 = \beta 1 = \lambda 1 = \acute{\omega} 1 = v1 = 1$ against the alternative hypothesis that there exists no unit root problem that is, $\alpha 1 \neq \beta 1 \neq \lambda 1 \neq \acute{\omega} 1 \neq v1 < 1$.

2.3 Bounds test approach to cointegration

As pointed out by Emran, et al. (2007), the bounds test approach to cointegration is preferred to other conventional cointegration tests because it has several important advantages over other conventional tests. The approach effectively corrects for a possible endogeneity of explanatory variables. Another important advantage of the ARDL approach is that one can avoid the uncertainties created by unit root pre-testing as the test can be applied regardless of whether the series are I(0) or I(1). An added bonus of this approach is that unlike other conventional tests for cointegration, it can be applied to studies that have a small sample size (Narayan, 2005). In addition, both the short- and the long-run relationship can be simultaneously estimated. In this paper the ARDL approach to cointegration is estimated using the following unrestricted error correction (UREC) regressions:

$$\Delta InY_t = \alpha_1 + \sum_{i=1}^{p} \beta_{1i} \Delta InY_{t-i} + \sum_{i=0}^{p} \kappa_{1i} \Delta InCE_{t-i} + \sum_{i=0}^{p} \varpi_{1i} \Delta InE_{t-i} + \sum_{i=0}^{p} \Psi_{1i} \Delta InF_{t-i} + \eta_{1Y}\, InY_{t-1} + \eta_{2Y}\, InCE_{t-1} + \eta_{3Y}\, InE_{t-1} + \eta_{4Y}\, InF_{t-1} + \mu_{1t} \quad (1)$$

$$\Delta InCE_t = \alpha_2 + \sum_{i=0}^{p} \beta_{2i} \Delta InY_{t-i} + \sum_{i=1}^{p} \kappa_{2i} \Delta InCE_{t-i} + \sum_{i=0}^{p} \varpi_{2i} \Delta InE_{t-i} + \sum_{i=0}^{p} \Psi_{2i} \Delta InF_{t-i} + \eta_{1c}\, InY_{t-1} + \eta_{2c}\, InCE_{t-1} + \eta_{3c}\, InE_{t-1} + \eta_{4c}\, InF_{t-1} + \mu_{2t} \quad (2)$$

$$\Delta InE_t = \alpha_3 + \sum_{i=0}^{p} \beta_{3i} \Delta InY_{t-i} + \sum_{i=0}^{p} \kappa_{3i} \Delta InCE_{t-i} + \sum_{i=1}^{p} \varpi_{3i} \Delta InE_{t-i} + \sum_{i=0}^{p} \Psi_{3i} \Delta InF_{t-i} + \eta_{1v}\, InY_{t-1} + \eta_{2v}\, InCE_{t-1} + \eta_{3v}\, InE_{t-1} + \eta_{4v}\, InF_{t-1} + \mu_{3t} \quad (3)$$

$$\Delta InF_t = \alpha_4 + \sum_{i=0}^{p} \beta_{4i} \Delta InY_{t-i} + \sum_{i=0}^{p} \kappa_{4i} \Delta InCE_{t-i} + \sum_{i=0}^{p} \varpi_{4i} \Delta InE_{t-i} + \sum_{i=0}^{p} \Psi_{4i} \Delta InF_{t-i} + \eta_{1R}\ InY_{t-1} + \eta_{2R}\ InCE_{t-1} + \eta_{3R}\ InE_{t-1} + \eta_{4R}\ InF_{t-1} + \mu_{4t} \quad \ldots\ldots (4)$$

where $\ln Y_t$ is the log of real GDP, $\ln CE_t$ is the log of CO_2 emissions; $\ln E_t$ is the log of electricity supply, InFt is the log of fossil fuel consumption and the sign Δ is the first-difference operator. The parameters β, κ, ϖ, and Ψ are the short-run dynamic coefficients, while the parameters η_1 to η_{4Y} function as the long-run multipliers of the underlying ARDL model.

In Eq. (1) tests for cointegration are carried out by testing the joint significance of the lagged levels of the variables using the F-test where the null of no cointegration is defined by H_O: $\eta_{1Y}=\eta_{2Y}=\eta_{3Y}=\eta_{4Y}=0$ against the alternative that H_1: $\eta_{1Y} \neq 0$, $\eta_{2Y} \neq 0$, $\eta_{3Y} \neq 0$, $\eta_{4Y} \neq 0$. Other tests for cointegration in Eqs. (2),(3), and(4), can also be carried out using similar procedures. The asymptotic distribution of the F-statistic is non-standard under the null and it was originally derived and tabulated by PSS but later modified by Narayan (2005). Two sets of critical values are provided: one, which is appropriate when all the series are I(0) and the other for all the series that are I(1).

According to PSS, in testing for cointegration, if the computed Fstatistic falls above the upper critical bounds, a conclusive inference can be made regarding cointegration without the need to know whether the series were I(0) or I(1). In this case, the null of no cointegration is rejected regardless of whether the series are I(0) or I (1). Alternatively, when the test statistic falls below the lower critical value, the null hypothesis is not rejected regardless of whether the series are I(0) or I(1). In contrast, if the computed test statistic falls inside the lower and the upper bounds, a conclusive inference cannot be made unless we know whether the series were I(0) or I(1). To ascertain the goodness of fit of the ARDL model, the stability test is conducted by employing the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMsq).

2.4 Granger Causality Analysis

Granger causality is an estimation technique used in examining whether one variable can help predict another economic variable. To test for causality, in the Granger sense, involves using *F*-tests to investigate whether lagged information on say fossil fuel consumption provides any statistically significant information about carbon emissions in the presence of lagged fossil fuel consumption. If it is found to be significant then fossil fuel consumption does granger cause carbon emissions and when it is insignificant there is no causality. According to Granger's theorem when the variables are cointegrated, the simple granger causality is augmented with the Error Correction Term (ECT), derived from the residuals of the appropriate cointegration relationship to test for causality. Thus, we estimate a Vector error correction mechanism (VECM) for the Granger causality test for our problem at hand. The VECM representation is as follows:

$$\Delta CE_t = \eta_1 + \sum_{i=1}^{p} \beta_{1i} \Delta Y_{t-1} + \sum_{i=1}^{p} \kappa_{1i} \Delta CE_{t-1} + \sum_{i=1}^{p} \varpi_{1i} \Delta E_{t-1} + \sum_{i=1}^{p} \Psi_{1i} \Delta F_{t-1} + \alpha_1 \mathrm{ECM}_{1t-1} + \mu_t \ldots (5)$$

$$\Delta Y_t = \eta_2 + \sum_{i=1}^{p} \beta_{2i} \Delta Y_{t-1} + \sum_{i=1}^{p} \kappa_{2i} \Delta CE_{t-1} + \sum_{i=1}^{p} \varpi_{2i} \Delta E_{t-1} + \sum_{i=1}^{p} \Psi_{2i} \Delta F_{t-1} + \alpha_2 \mathrm{ECM}_{2t-1} + \mu_t \ldots (6)$$

$$\Delta E_t = \eta_3 + \sum_{i=1}^{p} \beta_{3i} \Delta Y_{t-1} + \sum_{i=1}^{p} \kappa_{3i} \Delta CE_{t-1} + \sum_{i=1}^{p} \varpi_{3i} \Delta E_{t-1} + \sum_{i=1}^{p} \Psi_{3i} \Delta F_{t-1} + \alpha_3 \mathrm{ECM}_{3t-1} + \mu_t \ldots (7)$$

$$\Delta F_t = \eta_4 + \sum_{i=1}^{p} \beta_{4i} \Delta Y_{t-1} + \sum_{i=1}^{p} \kappa_{4i} \Delta CE_{t-1} + \sum_{i=1}^{p} \varpi_{4i} \Delta E_{t-1} + \sum_{i=1}^{p} \Psi_{4i} \Delta F_{t-1} + \alpha_4 \mathrm{ECM}_{4t-1} + \mu_t \ldots (8)$$

where CE is carbon emission, *Y* is economic growth, *E* is electricity consumption, *F* is fossil fuel consumption and α is the adjustment coefficient. ECT_{t-1} expresses the error correction term of the equations. The sign Δ is the first-difference operator; the optimum lag length *p* is selected based on the Schwarz-Bayesian information criteria (SBC) or Akaike Information Criteria (AIC); μ_t's are the independently and normally distributed error terms with zero mean and constant variance, while *t* denotes the time period. In equation (5), the energy variables granger causes carbon emissions if their coefficients and α are significantly different from zero. *F*-statistic is used to test the joint null hypothesis that the coefficients are equal to zero, and *t*-test is employed to estimate the significance of the error correction coefficient. It is important to note that a significant error correction coefficient indicates causality in the long run. However in all, the regressions may lead to one or more of the following three scenarios: 1) Unidirectional causali)ty from a variable to another. 2) Bi-directional causality or feedback effects between two variables. 3) Independence or neutral effect. In this case there is no granger causality.

3. Empirical Results and Discussion

3.1 Unit root

Table 2 shows the ADF and P.P unit root results for all the variables. The table indicates that all the variables are integrated or stationary at the first difference, I(1). In the presence of I(2) or higher order variables, the computed statistics provided by PSS and Narayan (2005) are not valid (Ang, 2007). This implies that we can confidently apply the PSS-ARDL methodology for testing for cointegration.

Table 2. ADF and Phillips- Peron Unit Root Test Results

Variable	**ADF test statistic**		**P-P test statistic**	
	First Difference	Critical values at 1% level	First Difference	Critical values at 1% level
Real GDP(InY)	-3.742	-2.628	-5.069	-2.626
Carbon Emission (InCE)	-4.871	-2.628	-5.898	-2.626
Electricity Supply(InE)	-3.279	-2.628	-6.569	-2.626
Fossil Fuel Consumption (InF)	-3.493	-2.628	-4.972	-2.626

Notes: The ADF analysis is based on optimal lag length of 1 while that of PP test is based on lag length of 3

3.2 Bounds test cointegration result

Having examined the time series characteristics of our data, the next step is where equations (1) – (4) are estimated to examine the long-run relationships among the variables. As suggested by Pesaran and Shin (1999) and Narayan (2004), since the observations are annual, we choose 2 as the maximum order of lags in the ARDL and estimate for the period of 1971-2009.We used the Akaike Information Criterion (AIC) to determine the optimal number of lags to be included in the conditional ECM (error correction model) since it produced better estimates than the Schwarz-Bayesian information criteria (SBC). The results of the cointegration tests are presented in Table 3. Evidence from the table indicates a long-run cointegrating relationship among the series under consideration.

Table 3. F-statistic results of the joint null hypothesis that the coefficients of the levels of the lagged independent variables are zero.

F-Statistic	Lags	
	1	2
F_{lnY}(Y|lnCE, lnE, InF)	3.8977**	2.0019
F_{lnCE}(CE|lnY, lnE, InF)	4.6205**	7.1442***
F_{InF}(F|lnCE,InY,InE,)	2.7326**	1.9663
F_{lnE}(E|lnCE, lnY, InF)	1.0062	1.0010

Notes: The asymptotic critical value bounds are obtained from Table C1(iii) Case III: unrestricted intercept and no trend for k= 4. Lower bound I(0) = 2.86 and upper bound I(1) =4.01 at 5% significance level, while at the 1% significance level lower bound I(0) = 3.74 and upper bound I(1) = 5.06(See Pesaran *et al*. 2001). The lag structure was selected based on the Akaike Information Criterion. *** and ** denotes the rejection of the null hypothesis at 1% and 5% significance levels respectively.

The calculated F-statistic of 7.1442 denoted by FlnCE(CE|lnY, lnE, InF), is higher than the upper bound critical value of 5.06 at 1% for 4 variables (Table CI(iii) Case III: unrestricted intercept and no trend) as tabulated in Pesaran et al (2001). This shows that the null hypothesis of no cointegration among economic growth, CO_2 emissions, electricity supply, and fossil fuel consumption is rejected at the optimal lag length of 2. On the other hand, when the other series (economic growth, electricity supply and fossil fuel consumption) were used as dependent variables no cointegrating relationship was found. Having established the existence of cointegration among the series, we estimated the long-run coefficients which are presented in Table 4.

Table 4. Estimated Long Run Coefficients using the ARDL Approach
ARDL (1, 0, 2, 0) selected based on AIC
Dependent variable is INCE

Regressor	**Coefficient**	**Std.Error**	**T-Ratio [Pr.]**
INY	1.351	0.637	2.11[.020]**
INE	1.231	0.383	3.21[.003]***
INF	1.586	0.321	4.93[.000]***
CONST	0.838	0.813	1.03[.310]

Notes: ***and **denote significant levels at 1% and 5% respectively

Table 4 shows that most of the variables are statistically significant and conform to a priori expectation except the sign of electricity supply coefficient which is positive. Electricity which is a clean energy is expected to reduce CO_2 emissions but in Nigeria, higher electricity supply which is inadequate and unreliable promotes the use of dirty fuels that increases CO_2 emissions. The results from the table also indicate that a 1% increase in economic growth leads to 1.35% increase in CO_2 emission while the long-run elasticity of CO_2 emission growth with respect to fossil fuel consumption is 1.58% indicating that for each 1% increase in fossil fuel consumption, CO_2 emission growth rise by 1.58%. Intuitively, this implies a case of inefficient energy consumption. This result conforms to the findings of Chebby and Boujelbene (2008) and Omisakin (2009) in the case of Tunisia and Nigeria, respectively.

The short-run dynamics results are reported in Table 5. An examination of the estimated result below shows that the overall fit is satisfactory at the value of R^2 =0.636. This shows that the independent variables used in our model jointly accounted for 63.5 percent of the total variation in CO_2 emission growth.

Table 5. Error Correction Representation for the parsimonious ARDL Model
ARDL (1, 0, 2, 0) selected based on AIC.
Dependent variable is dINCE

Regressor	**Coefficient**	**Std.Error**	**T-Ratio [Pr.]**
dINY	1.140	0.541	2.10[.051]**
dINE	1.012	0.224	4.51[.000]***
dINE(-1)	0.193	0.127	1.51[.139]
dINF	1.242	0.527	2.35[.029]**
dCONST	0.329	0.348	0.94[.352
Ecm(-1)	-0.692	0.120	-5.74[.000]***

Notes: R^2=0.636; Adjusted R^2=0.624; F-stat.(5,31)= 7.6540 [000]***; DW Statistic = 1.9679
Notes: *** and ** denote significant levels at 1%, and 5% respectively

Evidence from the table is reinforced by the long-run estimates presented in table 3. The elasticity status of our model shows that economic growth in the present period, electricity supply in the present period and fossil fuel consumption in the present period had coefficients of elasticity that are greater than one. This shows that CO_2 emission in Nigeria is highly responsive to changes in economic growth, fossil fuel consumption and electricity supply. It also implies that economic growth, electricity supply and fossil fuel consumption are some of the major determinants of CO_2 emission growth in Nigeria.

The coefficient of the ECM (-1) as could be observed in Table 5 is correctly signed (negative), and highly significant, showing that the model has a self-adjusting mechanism for adjusting the short-run dynamics of the variables with their long run values. This implies that there is a long-run relationship between CO_2 emission and its determinants. The speed of adjustment to equilibrium is given by the coefficient of ECM (-1) as -0.69. This speed is very high, indicating that a deviation in CO_2 emission growth from equilibrium is corrected by as high as 69 percent the following year.

3.3 Results of Causality test

Table 6 presents the results for the granger causality test. The Akaike Information Criterion was used in determining the lag length selection. The results from the table point to a bi-directional causality between fossil fuel consumption and economic growth in both the short run and long run indicating that Nigeria is energy depended economy. In other words, fossil fuel consumption causes changes in the industrial and commercial sectors where fossil fuel has been used as basic energy input while expansion in economic activities causes changes in fossil fuel consumption.

Table 6. The Result of Causality Test

NULL HYPOTHESES	SOURCE OF CAUSATION				
	SHORTRUN				LONGRUN
	InCE (F-stats)	**InF** (F-stats)	**InE** (F-stats)	**InY** (F-stats)	**ECT_{t-1}** (t-stats)
InCE does not cause **InY**	1.98	-	-	-	0.62
InY does not cause **InCE**	-	-	-	4.06***	3.77***
InY does not cause **InF**	-	-	-	4.21***	-2.05**
InF does not cause **InY**	-	3.23**	-	-	-1.89*
InCE does not cause **InF**	0.37	-	-	-	1.04
InF does not cause **InCE**	-	2.14**	-	-	4.91***
InY does not cause **InE**	-	-	-	0.83	0.11
InE does not cause **InY**	-	-	1.10	-	1.43
InE does not cause **InCE**	-	-	2.33**	-	6.06***
InCE does not cause **InE**	1.11	-	-	-	0.21

Notes: ***, ** and * denote significant levels at 1%, 5% and 10% respectively

Table 6 also indicates a unidirectional causality running from economic growth to CO_2 emissions without feedback indicating that changes in economic growth affects CO_2 emissions. This implies that policies aimed at reducing CO_2 emissions will not impede economic growth in Nigeria. On the causal relationship between fossil fuel consumption and CO_2 emissions, as can been seen from Table 6, changes in fossil fuel consumption affects CO2 emissions. This implies that the introduction of low carbon emission technologies and reducing the consumption of fossil fuels are viable options that can help to reduce carbon dioxide emissions.

Another interesting revelation from the causality test is the absence of a causal link between economic growth and electricity supply. This implies that electricity supply has not impacted significantly on economic growth in Nigeria owing to the electricity crises that has paralysed economic activities over the years.

Consistent with the results from the long-run estimates presented in Table 4, the causality results revealed that changes in electricity supply influences CO_2 emissions. This implies that electricity crises can encourage the use of dirty fuels that promote CO_2 emissions.

3.4 CUSUM and CUSUMSQ test results

Cumulative sum **(CUSUM)** and cumulative sum of squares **(CUSUMSQ)** tests have been employed to investigate the stability of long and short run parameters of the ARDL model as suggested by Pesaran et al. (1999, 2001). Figures 1 and 2 specify that plots for CUSUM and CUSUMSQ are between the critical boundaries at 5 % level of significance. This confirms the accuracy of long and short run parameters in the model. Therefore, the preferred CO_2 emission model can be used for policy decision-making purposes, such that the impact of policy changes considering the explanatory variables of CO_2 emission equation will not cause major distortion in the level of CO_2 emissions growth, since the parameters in this equation seem to follow a stable pattern during the estimation period.

Figure 1. Plot of CUSUM

Plot of Cumulative Sum of Recursive Residuals

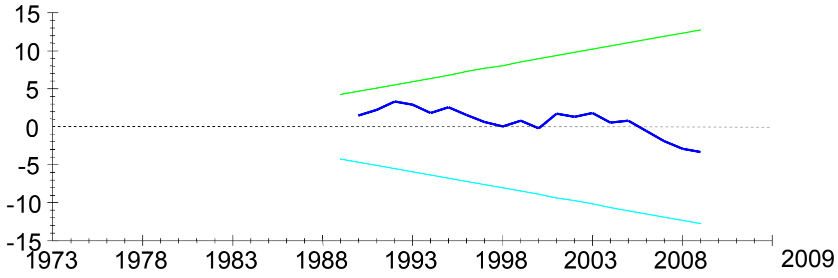
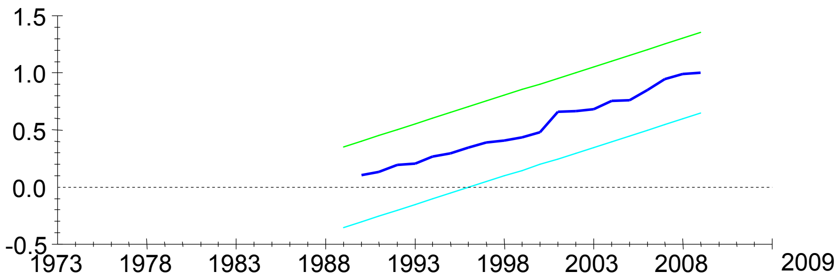


Figure 2. Plot of CUSUMSQ

Plot of Cumulative Sum of Squares of Recursive Residuals



4. Policy Relevance and Conclusion

This paper employed the ARDL bounds test cointegration procedure and the VECM based causality tests to examine the dynamic linkages among economic growth (GDP), electricity supply, fossil fuel consumption and CO_2 emissions for Nigeria during the period 1971–2009 in a multivariate framework. The bounds test result as indicated in the short run and long run estimates revealed that CO_2 emissions in Nigeria is highly responsive to changes in GDP growth, fossil fuel consumption and electricity supply. The results of Granger causality tests indicate a bi-directional causal relationship between fossil fuel consumption and GDP as well as a unidirectional causality running from electricity supply to carbon emissions; from fossil fuel consumption to CO_2 emissions and from economic growth to CO_2 emissions; all without a feedback. The Granger causality also found the absence of a causal link in the case of electricity supply and economic growth.

These empirical results provide useful insight to policy formulation and implementation especially as the nation aspires to transform into a fully industrialized economy in the near future. Rapid industrialization requires higher and/or more efficient consumption of energy products. Given the elastic effects of GDP growth and fossil fuel consumption on CO_2 emissions and the attendant consequences on the environment, there is much scope for the development and entrenchment of energy management and efficiency strategies. Moreover, policies aimed at diversifying energy source should be applied to reduce the reliance on fossil fuel. Nigeria is endowed with abundant sources of renewable energy (wind, solar, biomass, hydropower, Natural gas) that can simultaneously address both the energy needs as well as the environmental concerns due to CO_2 emissions. ECN (2008) has shown that these resources are yet to be fully tapped due to lack of funding, infrastructure and political will. In addition, a holistic energy sector reforms and massive investment in the energy sector especially electricity infrastructural development aimed at increasing efficient energy consumption through energy service availability, accessibility and affordability will in the longrun promote a healthier environment ,engender economic growth and ensure sustainable development of Nigeria

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