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DO STRUCTURAL BREAKS MATTER IN THE GROWTH-ENVIRONMENT NEXUS IN NIGERIA?

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Abstract

This paper examined the nexus between energy consumption, CO2 emissions and economic growth in Nigeria, for the period 1970-2011 within a dynamic multivariate framework. Specifically, we rely on the Zivot-Andrews unit root test, Gregory-Hansen cointegration test and subsequently estimate our model using the Granger non-causality test (proposed by Toda and Yomamoto). Our findings showed that even with the observed break points in 1991 and 1992, energy consumption, CO2 emissions and economic growth were cointegrated. However, perhaps due to the structural shifts, no causal relationship running from CO2 emission and energy consumption to economic growth was observed. We also found that the effect of CO2 emissions and energy consumption on growth in Nigeria is time-varying between, before and after the structural breakpoint. An important policy implication resulting from our analysis is the need for government to re-focus its energy policies in pursuit of renewable energy sources that are environmentally friendly and which will have minimal effects on long-term growth in terms of CO2 emissions.

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1. Introduction

The debate on the causes and effects of global warming rages on and largely remains unsettled. Proponents of global warming have argued that global emissions of carbon dioxide (CO_2) remain a major source of global warming. Indeed, CO_2 emission has increased by 3% in 2011, reaching an all-time high of 34 billion tonnes (NEAA, 2012). The alarming threat and attendant consequence of climate change on overall socio-economic development have made the relationship between energy consumption, environmental pollutants and economic growth a contentious issue. Although the use of various energy sources remains crucial to economic activities, its optimal use such that emission of pollutants are reduced to the barest minima remains critical to the long-run growth of low, middle, and high-income countries.

The Nigerian economy has grown by an average rate of about 6% over the past one decade. The economy grew at 7.9% in 2010; exceeding the 7% recorded in 2009. This impressive growth performance outstrips the average of 6.7% observed for the period 2006-2010. In spite of this remarkable development, the supply of electricity -the main source of energy in Nigeria- remains fitful. The paucity of electricity supply has led to a shift to alternative sources of power, which largely require burning of fossil fuels. This could have also contributed to the increased emission level. Globally, carbon dioxide (CO_2) emissions account for more than 75% of greenhouse gas emissions; 80% of which is generated by the energy sector (Akpan and Akpan, 2012). The effect of this trend is worrisome given the plausible enormous detrimental effects of pollutant emissions on the environment.

The energy consumption index in Nigeria increased from 2.8% in 2010 relative to the increase and dip of 4.9% and 1.9% observed accordingly in 2008 and 2009. As noted by the CBN (2009, 2010), in absolute terms, energy consumed stood at 19.1million tonnes of coal equivalent (TCE) in 2010, from 20.4million and 18.3million TCE in 2008 and 2009, respectively. In specific terms, consumption of petroleum products, electricity, hydropower and coal consumption exhibited a boom and bust like trend. Consequent upon the above, emission of green house gases stood at a staggering 49.6 and 41.2million tonnes in 2008 and 2009. In sum, the average change of pollutants emitted between 1990 and 2009 was 41.3%. This rather appalling scenario, *inter alia*, stimulates this study.

It is pertinent to note that the magnitude of emission of carbons in the country's atmosphere varied between sectors and type of energy used. As at 2009, total CO_2 emissions from combustion fuels stood at 41.2% while electricity and heat generated 8.2%. The manufacturing and construction sectors emitted 3.1% while the energy industry's own use stood at 4.5%. The transport sector was the largest emitter of CO_2 with almost 24% with the road sector component dominating. Other sectors cumulatively emitted about 2%.

Four main theoretical views exist in the literature on the relationship between energy consumption and economic growth. Apergis and Payne (2009) aptly captured these four perspectives as: growth, conservation, neutrality, and feedback hypothesis.[1] There are plethora empirical studies that explored into the relationship between energy consumption and economic growth across space and time, with diverse conclusions and implications as the theoretical front [see for instance, Lee and Chang (2007), Akinlo (2008), Odhiambo(2009, 2010), Apergis and Payne (2010), Kouakou (2011), Binh, (2011), Dagher and Yacoubian (2012), Shahbaz *et al*. (2012), Islam *et al*.(2013), Ouedraego (2013), and Dergiades *et al*. (2013)]. Ozturk (2010) and Payne (2010) provide generous documentation of those studies. These two authors submitted that the literature produced conflicting results and there is no

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[1] The growth hypothesis posits that energy consumption plays a key role in economic growth. Conservation argues that reduction in energy conversation will not adversely affect economic growth. Neutrality submits that no impact on economic growth while feedback points that both energy consumption and economic growth are complements. See Apergis and Payne (2010) for details.

consensus either on the existence or on the direction of causality between energy consumption (electricity consumption) and economic growth. In view of this, considerable efforts have been exerted by several studies to dig further into the relationship. Some studies follow Payne's (2010) suggestion by exploring the environmental implication of the linkage. Hence, focus has shifted to the link among CO_2 emission, energy consumption and economic growth (see for instance, Chebbi (2009) for Tunisia, Menyah and Wolde-Rufael (2010) for South Africa, Tiwari (2011a, 2011b) for India, Akpan and Akpan (2012) for Nigeria).

There are a number of attempts to examine the nexus in Nigeria, [see for instance, Omotor (2008), Odularu and Okonkwo (2009), Dantama *et al*. (2012), and Olusanya (2012)]. Most of these studies only focused on the effect of energy and/or electricity consumption on economic growth, neglecting the consequence of persistent energy depletion in form of CO_2 emission on the economy. While these studies have offered plausible explanations for this crucial nexus, the approach employed are mostly based on Johansen and Juselius or Engle and Granger cointegration and/or Granger causality approach especially for studies carried out in Nigeria.[2] The present effort differs in this direction. We propose to use the Gregory-Hansen cointegration test and the Toda-Yamamoto causality test to assess the relationship. This is in view of the significant regime shifts observed for instance following the oil price shock of 1973 and 1979, adoption of structural adjustment programme in 1986, Nigeria's political transition attempt in 1992, Asian financial crisis in 1997, military to democratic rule in 1999, banking sector consolidation in 2004 and global economic slowdown in 2008 amongst others.

The Gregory and Hansen (1996) tests for structural break cointegration allows for cointegrating vectors to change at an unknown time period. This is in view of the fact that, in general, failure to account for breaks can produce misleading tests leading to incorrect inference. In the same vein, we consider the Granger non-causality test using the Toda-Yamamoto (T-Y) procedure which is applicable regardless of whether a series is $I(0)$, $I(1)$ or $I(2)$, not-cointegrated or cointegrated of any arbitrary order. This implies that it avoids the potential bias associated with unit root and cointegration tests (see Rambaldi and Doran, 1996) which some other studies have utilised.[3]

Therefore, the major objective of this study is to test an econometric model in order to identify the main economic fundamentals surrounding the interplay between economic growth, CO_2 emission and energy consumption in Nigeria using annual data from 1970 to 2011. The focal point would be examining the causal relationship between CO_2 and energy consumption on economic growth. A priori, we expect a positive relationship between energy consumed and growth while a negative relationship is expected between CO_2 emission and growth. For labour and capital, the other control variables, we expect a positive association with growth. The sequence of the study is clear. Following an introductory section, Section two presents the methodology. In section three, the empirical analysis and findings are discussed while policy implications and concluding remarks are covered in section four.

2. Methodology

2.1. Analytical Framework and Model Specification

Energy use remains a major source of pollutant emissions and the Environmental Kuznet Curve (EKC) remains a valid hypothesis for explaining the relationship between emission of toxic gases and economic growth (See Shahbaz, Lean and Shabbir, 2012; Vaona, 2012; Wandji, 2013). Perceptibly, these studies have failed to consider CO_2, energy use and

[2] In addition, these studies have not considered the possible structural breaks in energy consumption in Nigeria as a result of the change from a regulated to deregulated regime which may have an effect on energy consumption.
[3] The need for carrying out such a study arises from the critical role cannot be understated given the role of climate change as a matter of global and national discourse and concern. Thus, in line with best international practice, governments' economic policy decisions should be environmentally friendly and sustainable.

economic growth within the same framework which is a major limitation for the use of the bi-variate EKC model. While the new growth model provides platform for multi-variate analysis, it offers insightful explanations on issues that affect climate change particularly within the context of sustainable economic growth. Moreover, Stern (2004) argued that the EKC literature is econometrically weak as little or no attention has been paid to stochastic trends or omitted variable issues. We address these issues in the new growth model utilised for this study by taking the first difference of the variables in the contemporaneous causality model estimated. As regards omitted variables, the literature provides ample evidence of inclusion of relevant variables in the model.

This paper adopts and adapts the dynamic endogenous growth model used by Menyah and Wolde-Rufael (2010) as the basis for our empirical specification. However, Romer (2006) had argued that since environmental considerations are absent in such models, many now believe, following Thomas Malthus's classic argument that these considerations are critical for long-run economic growth. It is against this backdrop that we extend the model to include CO_2 emission as additional independent variables. In addition, we account for the traditional control variables (labour and capital) as determinants of growth in Nigeria. The basic empirical specification of the study is thus presented as follows:

$$LNGDP_t = \beta_0 + \beta_1 LNPOP_t + \beta_2 LNINV_t + \beta_3 LNCOE_t + \beta_4 LNECON + e_t \quad (1)$$

Where LNGDP represents log of gross domestic product, LNPOP represents log of working population, LNINV denotes log of capital (gross fixed capital formation is used as a proxy), LNCOE stands for log of CO_2 emissions, LNECON represents the log of aggregate energy consumption while e_t is the error term assumed to be white noise. A priori, we expect β_1>0, β_2>0, β_3>0 and β_4>0.

2.2. Estimation Procedures

Prior to the cointegration and causality test, the mean reversion test of the series was carried out using the Zivot-Andrew (Z-A) Unit Root Test.[4] Several studies have found that the conventional unit root tests fail to reject the unit root hypothesis for the series that are actually trend stationary with a structural break (Binh, 2011).[5,6,7]

Gregory-Hansen (G-H) Co-integration Test[8]

We employed the Gregory and Hansen (1996) tests for co-integration where the structural break is test-determined and the co integrating vectors are allowed to change at an unknown time period. As earlier noted, this is because in general, failure to account for breaks can produce misleading results leading to incorrect inference.[9] Therefore, it is necessary to employ non-linear techniques for testing co-integration if the series have structural breaks. One of the widely used methods is the Gregory and Hansen (1996) threshold co-integration test. And the test equations are expressed as follows:

Level Shift Model: $y_{1t} = \mu_1 + \mu_2 \varphi_{t\tau} + \alpha^T y_{2t} + e_t$ (2)

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[4] For comparison, the Augmented Dickey Fuller (ADF) test was conducted but not presented here for want of space.

[5] For example, the Dickey and Fuller (1979) type test for unit root is not consistent if the alternative is that of a stationary noise component with a break in the slope of the deterministic trend while the Perron (1989) test has been generally criticized for treating the time of break as exogenous or the time of break is known a priori (Altinay and Karagol, 2004).

[6] For details of this test see Zivot and Andrew (1992)

[7] The Zivot and Andrews (1992) unit root test suggests that we reject the null hypothesis of a unit root if computed *t* is less than the left-tail critical *t* value.

[8] The Engle and Granger cointegration test is also used for comparability purpose and can be found in appendix.

[9] Esso (2010) opined that the cointegration framework of Engle and Granger, and Johansen have limitations especially when dealing with economic data containing the structural breaks. In this case, we tend to reject the hypothesis of cointegration, albeit one with stable cointegrating parameters. The reason is that the residuals from cointegrating regressions capture unaccounted breaks and thus typically exhibit non-stationary behavior.

Level Shift and Trend Model: $y_{1t} = \mu_1 + \mu_2 \varphi_{t\tau} + \beta t + \alpha^T y_{2t} + e_t$ (3)

Regime Shift Model: $y_{1t} = \mu_1 + \mu_2 \varphi_{t\tau} + \alpha^T y_{2t} + \alpha^T y_{2t} \varphi_{t\tau} + e_t$ (4)

Where y is the observed data and μ_1 and μ_2 represent the intercept before the shift and the change in the intercept at the time of the shift; φ is the dummy variable that captures structural change;[10] β is the trend slope before the shift; α is the slope coefficients and are assumed to be constant. Y_{1t} represents the dependent variable (LNGDP) and while Y_{2t} is a vector of independent variable(s) (LNPOP, LNINV, LNCOE and LNECON). The standard methods to test the null hypothesis of no co-integration are residual-based and are obtained when equations (2, 3 and 4) are estimated using the ordinary least square (OLS) and the unit root tests are applied to the regression errors (Gregory and Hansen, 1996).

Toda-Yamamoto (T-Y) Granger Causality Test

This study makes use of the T-Y Granger non-causality technique to examine the causal relationship between CO_2 emission and energy use to economic growth.[11] The T-Y approach fits a standard VAR model on levels of the variables and therefore makes allowance for the long-run information often ignored in systems that require first differencing and pre-whitening (Clarke and Mirza, 2006). The approach employs a modified Wald test for restrictions on the parameters of the VAR (k) where k is the lag length of the system. The basic idea of the T-Y approach is to artificially augment the correct order, k, by the maximal order of integration, say d_{max}. Once this is done, a $(k+d_{max})^{th}$ order of VAR is estimated and the coefficients of the last lagged d_{max} vectors are ignored (Caporale and Pittis, 1999).[12]

To undertake this test, we estimate the following system of equations:

$$\begin{bmatrix} \ln GDP_t \\ \ln POP_t \\ \ln INV_t \\ \ln COE_t \\ \ln ECON_t \end{bmatrix} = A_0 + A_1 \begin{bmatrix} \ln GDP_{t-1} \\ \ln POP_{t-1} \\ \ln INV_{t-1} \\ \ln COE_{t-1} \\ \ln ECON_{t-1} \end{bmatrix} + A_2 \begin{bmatrix} \ln GDP_{t-2} \\ \ln POP_{t-2} \\ \ln INV_{t-2} \\ \ln COE_{t-2} \\ \ln ECON_{t-2} \end{bmatrix} + A_3 \begin{bmatrix} \ln GDP_{t-3} \\ \ln POP_{t-3} \\ \ln INV_{t-3} \\ \ln COE_{t-3} \\ \ln ECON_{t-3} \end{bmatrix} + A_4 \begin{bmatrix} \ln GDP_{t-4} \\ \ln POP_{t-4} \\ \ln INV_{t-4} \\ \ln COE_{t-4} \\ \ln ECON_{t-4} \end{bmatrix} + \begin{bmatrix} \varepsilon_{\ln GDP_t} \\ \varepsilon_{\ln POP_t} \\ \varepsilon_{\ln INV_t} \\ \varepsilon_{\ln COE_t} \\ \varepsilon_{\ln ECON_t} \end{bmatrix} \quad (5)$$

In Eq. (5), $A_1 \ldots A_4$ are four 5×5 matrices of coefficients with A_0 being the 5×1 identity matrix, ε_s are the disturbance terms with zero mean and constant variance. From Eq. (5) we can test the hypothesis of granger causality amongst the variables with the following hypothesis: $H_0 = a_{ij}^1 = a_{ij}^2 = a_{ij}^3 = a_{ij}^4 = 0$ and an opposite of non-causality with the following hypothesis: $H_0 = a_{ji}^1 = a_{ji}^2 = a_{ji}^3 = a_{ji}^4 = 0$.

Data Issues

Annual data covering the period 1970–2011[13] is utilised for this study and the variables of interest are total energy consumption (kg of oil equivalent) (LNECON), CO_2 emission (LNCOE) measured in kilotonnes (kt) and real GDP (GDP) measures the economic growth. We proxy the traditional variables within the neo-classical growth model-labour and

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[10] $\varphi_t = \begin{bmatrix} 0 \;\; if \;\; t \le (n\tau) \\ 1 \;\; if \;\; t > (n\tau) \end{bmatrix}$ where the unknown parameter $\tau \in (0,1)$ implies the timing of the break point, and $(n\tau)$ denotes integer part

[11] As pointed out by Clarke and Mirza (2006) unit root and cointegration might suffer from size distortions, which often imply the use of an inaccurate model for the non-causality test. To obviate some of these problems, based on augmented VAR modelling, T-Y introduced a Wald test statistic that asymptotically has a chi square ($\chi 2$) distribution irrespective of the order of integration or cointegration properties of the variables.

[12] An optimal lag length of 3 was selected based on the Akaike Information criteria while the maximum order of integration, d_{max}, is 1 and thus, $(k+d_{max})$ yields VAR (4).

[13] The sample size is 42 years.

capital accordingly by working population (LNPOP) and gross fixed capital formation (LNINV). All the data used for the analysis were obtained from the World Bank Development Indicators (online). However, gross fixed capital formation was obtained from UNCTAD database (online). The unit of measurement of the variables are as follows: LNCOE (kt), LNECON (kt of oil equivalent), GDP growth (annual percentage), LNPOP (total working population) and LNINV (local currency unit). All variables excluding GDP growth rate are in logarithmic form.

3. Empirical Findings

3.1. Unit Root Test Results

The null hypothesis of the Z-A (1992) is that $\alpha = 1$, i.e. the series has a unit root with structural break in constant, trend or constant and trend stationary process. Table 1 shows sufficient evidence of rejecting the null hypothesis of the presence of a unit root with structural breaks at the 1%, 5% or 10% level. For some variables that did not fall within the 1%, 5% and 10% critical values, they were found to be significant at levels above the 50% critical value reported in Table 1, panel B, of Zivot and Andrews (2002). Thus, we conclude that the structural breaks in the series are not sturdy enough to generate any divergence with the results of conventional unit root tests. The Augmented Dickey Fuller (ADF) was carried out to aid comparison with the Z-A test results. This conventional unit root test results showed that all the variables are non-stationary at levels but became stationary after their first differences. It is pertinent to note that the ADF test treats regime shifts as exogenous.

Table 1: Zivot-Andrews Unit Root Test Results

Variable	Z-A (1992)								
	Model A			Model B			Model C		
	t	Breakpoint	Lag	t	Breakpoint	Lag	t	Breakpoint	Lag
LNCOE	-5.15**	2000	0	-4.21**	1997	0	-5.02**	2000	0
LNGDP	-4.22	1992	1	-2.39	1982	1	-3.72***	1992	1
LNINV	-5.08**	1983	3	-4.85*	1986	3	-5.82*	1983	3
LNPOP	-9.14*	1993	3	-6.60*	2005	3	-6.05*	2005	3
LNECON	-3.29***	2001	4	-3.47	2007	2	-4.05*	2001	2

Notes: The break locations i.e. intercept, trend and both, are denoted by Models A, B and C. *, ** and *** imply significance at 10%, 5% and 1% respectively based on percentage points of the asymptotic distribution critical values as provided by Zivot and Andrew (1992) table 2 page 30.
Source: Authors' computation

3.2. Co-integration Test Results

In the specification for our analysis, we assume a level shift with trend. The analysis is carried out with a maximum of 8 lags and the Akaike Information Criteria (AIC) is used to determine the optimal lag length, The results of the G-H co-integration test is presented in Table 2. We find evidence of a significant long-run relationship amongst the variables considered as the ADF and PP test statistic exceed the critical values at the 1%, 5% and 10% level. The Engle and Granger cointegration test conducted and presented in the appendix also validates the Gregory-Hansen co-integration test results as it shows the significance of the ADF statistic of the residuals of the estimated model. The result of the residual-based unit root test presented in Table 2 indicates that there exists a long-run relationship between economic growth and the variables considered. The implication of this finding is that there exists a causal relationship amongst the variables but there is no indication regarding the direction of causality.

Table 2: Gregory-Hansen Cointegration Test Results

Model	Level Shift	Level Shift with Trend	Regime Shift
ADF Procedure			
t-stat	-4.14	-5.78	-6.45
Lag	0	0	1
Break	1992	1992	1992
Phillips Procedure			
Za-stat	-25.26	-38.48	-45.33
Za-break	1992	1992	1992
Zt-stat	-4.19	-5.85	-7.00
Zt-break	1992	1992	1992

Source: Authors' computation

The co integrating equations are presented in Table 3. The results showed that in the level shift model, CO_2 emissions negatively affected the growth of the economy while energy consumption, investment and labour positively affected economic growth. These long-run results (excluding CO_2 emission) concur to a priori theoretical expectations of the growth model relied upon. A similar result was observed with the level shift with trend model as all the variables carried the expected sign except the log of working population which was negatively related to growth. A slightly similar but distinct finding is observed for the case of the regime shift model where contrary to expectation, energy consumption was found to be negatively related to economic growth in the long-run. However, other variables carried the expected sign. Observably, a disparity between the coefficients is evident in LNPOP and LNECON for the three models and this may be attributed to the shift in the slope vector, change in intercept before or at the time of the shift and/or changes in cointegrating slope coefficients (See Gregory and Hansen, 1996).

Table 3: Co integrating Equations

Model	Level Shift		Level Shift with Trend		Regime Shift	
Variable	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
CONSTANT	-48.00	0.01	518.02	0.00	-104.84	0.00
LNCOE	-0.44	0.00	-0.42	0.00	-0.32	0.00
LNECON	0.12	0.92	3.45	0.00	-4.75	0.00
LNINV	0.72	0.00	0.48	0.00	0.65	0.00
LNPOP	3.97	0.03	-30.78	0.00	10.18	0.00
τ_1	-	-	0.83	0.00	-	-
τ_2	-0.20	0.26	-0.21	0.07	7.10	0.97
τ_2* LNCOE	-	-	-	-	-0.48	0.84
τ_2* LNECON	-	-	-	-	3.55	0.49
τ_2* LNINV	-	-	-	-	-0.83	0.45
τ_2* LNPOP	-	-	-	-	-1.71	0.91
Adjusted R-squared	0.99		0.99		0.99	
Prob(F-statistic)	0.00		0.00		0.00	
Durbin-Watson stat	0.71		1.29		1.38	

Note: τ_1 and τ_2 indicate deterministic trends.
Source: Authors' computation

Thus, we proceed to examine the causal linkage between energy consumption, CO_2 emission and economic growth in Nigeria using the augmented Granger non-causality test proposed by Toda and Yomamto (T-Y) (1995). The estimated vector autoregression model and Johansen co-integration test which are precursory procedures for carrying out the T-Y procedure were done but not presented here due to spatial constraints.

3.3. Granger Non-Causality Test Results

The result of the Toda-Yamamoto causality test is presented in panels 1 to 5 of Table 4. The results indicate that contrary to theoretical expectation, we cannot reject the null hypothesis of no causality from working population (LNPOP), energy consumption (LNECON), investment (LNINV) and CO_2 emissions (LNCOE) to economic growth (LNGDP). The elasticity of the estimated VAR model (not presented here) showed otherwise as labour for instance had a positive effect on GDP. However, the null hypothesis of no causality from economic growth and energy consumption to CO_2 emission is rejected. This implies that higher growth rates are associated with pollutant emissions and this is significant at 1% significance level. In the same vein, as expected, increased energy use intensifies emission of CO_2 at the 5% level. Likewise, a significant causal linkage from GDP, investment and working population to energy consumption is is observed. In sum, we have reasonable evidence that within a neo-classical growth model, energy consumption and emission of carbons do not lead to economic growth in Nigeria. What makes our finding differ with other previous similar studies may be the fact that they relied on the environmental Kuznets curve theory to examine the nexus while we considered the relationship within the new growth model. In addition, we considered structured breaks in the series which, affect Nigeria's long run growth.

Table 4: Toda-Yamamoto Causality Test Results

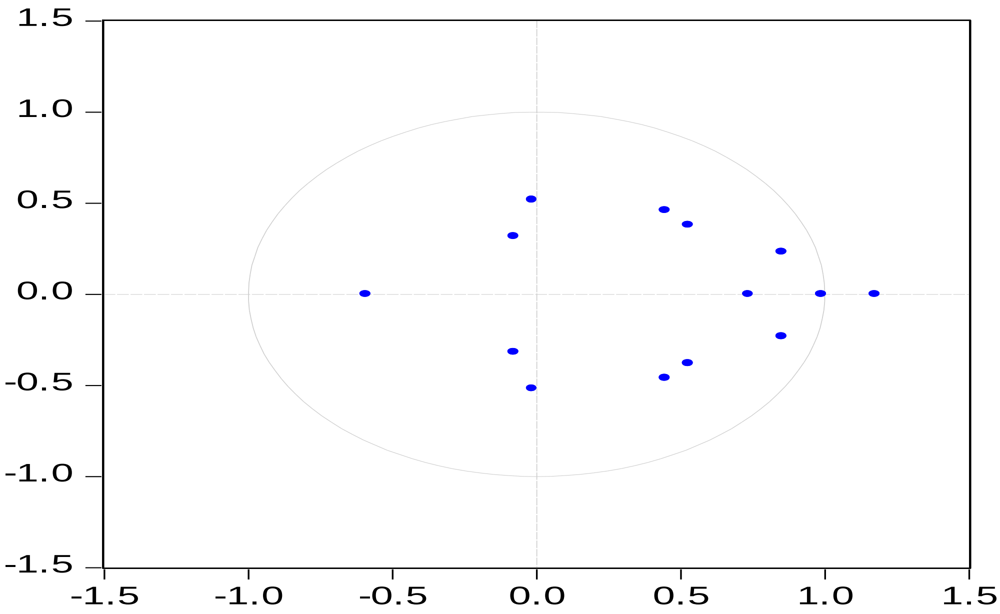
Panel 1: Dependent variable: LNCOE		
Excluded	MWALD	Prob.
LNECON	9.76	0.02
LNGDP	11.12	0.01
LNINV	1.94	0.58
LNPOP	2.46	0.48
All	39.61	0.00
Panel 2: Dependent variable: LNECON		
Excluded	MWALD	Prob.
LNCOE	1.74	0.62
LNGDP	11.49	0.00
LNINV	12.05	0.00
LNPOP	7.35	0.06
All	16.79	0.15
Panel 3: Dependent variable: LNGDP		
Excluded	MWALD	Prob.
LNCOE	0.25	0.96
LNECON	0.36	0.94
LNINV	1.12	0.77
LNPOP	1.04	0.78
All	7.16	0.84
Panel 4: Dependent variable: LNINV		
Excluded	MWALD	Prob.
LNCOE	0.32	0.95
LNECON	15.98	0.00
LNGDP	12.77	0.00
LNPOP	11.05	0.01
All	33.08	0.00

Panel 5: Dependent variable: LNPOP		
Excluded	MWALD	Prob.
LNCOE	17.95	0.00
LNECON	3.62	0.30
LNGDP	13.18	0.00
LNINV	17.20	0.00
All	90.12	0.00

Note: Sample (1970-2011), 39 observations were included
Source: Authors' computation

An examination of the residuals based on the LM test signifies the absence of serial correlation in our model when a maximum lag length of 3 was used. The estimated VAR and Toda-Yamamoto models are dynamically stable as indicated by the inverse root of the AR characteristic polynomial, thus the VAR on the basis of which the Toda-Yamamoto test is conducted satisfies the stationarity condition.

Inverse Roots of AR Characteristic Polynomial



Source: Authors' computation

4. Conclusion

This study examined the relationship between energy consumption, CO_2 emissions and economic growth in Nigeria. We relied on the new growth model as the theoretical underpinnings of the study and thus the basis of our empirical model specification. The study found the existence of a long-run relationship between the variables considered. While we did not find a causal relationship running from energy consumption and CO_2 emissions to growth, the latter was found to cause energy consumption and growth. This finding departs from theoretical expectation in relation to previous empirical studies carried out for Nigeria and this may be attributed to the observed break in the time series data. In addition most previous studies for Nigeria have relied on the Environmental Kuznets Curve hypothesis which did not account for traditional growth determinants. Yet, we find a significant causal relationship running from growth expansion to CO_2 emissions and energy consumptions. In other words, the economy expands, an increment is observed in per capita energy consumption and thus emissions of pollutants also increase. The policy implication of our finding buttresses the need for government to pursue green energy policies and diversify the country's energy sources. This may be done by considering renewable energy sources such as biomass, wind and solar amongst others such that CO_2 emissions are reduced to the barest minima and the long-run balanced growth path can be sustained. It may also be insightful to re-examine the relationship using disaggregated energy uses. This will further provide evidence for informed green energy policy decision that will focus on energy usage with significant CO_2 emission.

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Appendix

A 1: Energy Consumption, Carbon Emission and Nigeria's Economic Growth

Year	Electric power cons (kWh)	Energy use (kg of oil equivalent per capita)	CO2 emissions from gaseous fuel cons (kt)	CO2 emissions from liquid fuel cons(kt)	CO2 emissions from solid fuel cons (kt)	GDP growth
1970-1974	1926250000.00	624.21	489.91	7440.34	631.46	11.83
1975-1979	3266142857.14	654.64	2561.14	10127.73	663.20	3.91
1980-1984	5344800000.00	711.99	6118.76	28487.46	255.96	-3.85
1985-1989	7853000000.00	716.79	6723.81	33289.03	235.42	5.72
1990-1994	9297000000.00	735.83	9395.59	41192.88	229.55	3.63
1995-1999	9335200000.00	723.03	10892.46	27739.39	184.82	2.50
2000-2004	12443600000.00	737.17	14659.20	33262.62	49.14	6.19
2005-2009	18390800000.00	727.19	21935.99	29523.02	29.34	6.21
2010	21624000000.00	na	na	na	na	7.82
2011	na	na	na	na	na	6.67

Source: World Bank World Development Indicators (2013) Online