Reinvestigating the Relationship between CO_2 Emission, Energy Consumption and Economic Growth in Nigeria Considering Structural Breaks

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Abstract**—*This study reinvestigates the short and long run causal relationship between energy consumption, CO2 emission and economic growth in Nigeria while considering the presence of structural breaks for the period of 1980-2012. We applied two sets of unit root tests of which one set did not find structural breaks, but the other considered structural breaks. The Johansen test identified cointegration between economic growth and energy, electricity, gas consumption and CO2 emission for power generation while the Gregory and Hansen test only detected cointegration between economic growth and CO2 intensity. Our Granger causality result revealed bidirectional causality between GDP and energy consumption on the short-run while a unidirectional flow from GDP to energy consumption. GDP and gas consumption showed bidirectional causality in the short and long run while electricity consumption and GDP showed mixed unidirectional causality in the short and long-run. Unidirectional causality ran from GDP to CO2 emission from power generation and intensity in the short- and long-run. We suggest that energy conservation policy should not be implemented without considering its effect on economic growth. Gas development should be encouraged while the diversification of Nigeria's energy mix will reduce CO2 emission without affecting economic growth.*

Keywords—CO2 emission, energy consumption, economic growth, structural breaks, Nigeria.

I. INTRODUCTION

The issues of climate change and global warming have been the popular topic in climatology, environmental science and energy economics in recent years which is due to the adverse effect of the former on the latter. The risk associated with climate change is due to the emission of carbon dioxide from fossil fuels which is regarded as the main environmental threat from the existing energy system. Fossil fuels supply a large part of the total primary energy use in the world which accounts for almost 75% [1]. On the international scene, there is an increasing consensus in the scientific, economic and political communities who believe that a significant reduction in greenhouse gasses (GHG) emissions are vital to reducing the level or effect of climate change. In the energy sector, renewable energy systems contributed in its modest scale in the reduction of GHG emissions, while future projections show that renewable energy will play a significant role in the global energy supply [2].

The United Nation through the Kyoto Protocol (i.e. United Nation Framework Convention on Climate Change, UNFCCC) has made some efforts to reduce the impact of the impending doom of climate change and global warming. It has been through binding agreements on the reduction of fossil fuel consumption and promotion of renewable energy adaptation worldwide [3]. In 2014, the UNFCCC had 196 parties to its protocol and Nigeria was also a member who ratified the agreement on the 10th of December 2004 as the 130th member.

The issue of climate change affects both the developed and developing countries alike. According to the study carried out by the Pan African Climate Justice Alliance (PACJA) using climate models discovered the increasing temperature in Africa, especially the West African region. They projected that by 2020, the sea level may rise to 0.3m and 1m by 2050, which will lead to the loss of the Niger Delta in Nigeria through flooding. They also predicted that the temperature in Nigeria is bound to increase by 3.20C in

2050, and this will affect the nation's Gross Domestic Product (GDP) by 2-11% (See [4]).

Besides the climate change issue, Nigeria is still facing the challenges of meeting the ever increasing demand for energy by the country's growing population. To meet energy demand, the government has intensified its effort to improve energy supply which in turn has increased the country's CO2 emissions. Currently, climate change has moved from an environmental problem to a developmental issue in the Nigerian context. It is against this background that this paper intends to re-investigate the relationship that exists between CO2 emission from electricity and energy use (intensity), energy and power consumption, and economic growth in Nigeria considering the presence of structural breaks.

There is some literature that exists which attempts to investigate the nexus that exists between energy consumption, CO_2 emission, and economic growth (See Section 2), but these studies produced contradicting results. These studies usually employed the Augmented Dickey-Fuller unit root test, the Johansen cointegration, and the Granger causality approach. These studies did not consider the possible structural breaks in energy consumption in Nigeria, which is as a result of the change from a regulated to deregulated regime which may affect power consumption. Regime shifts can be significant and are observable in situations such as the oil price shock of 1973[1] and 1979[2], adoption of structural adjustment program in 1986[3], Nigeria's political transition attempt in 1992[4], Asian financial crisis in 1997[5], military to democratic rule in 1999[6], banking sector consolidation in 2004[7] and global slowdown in 2008[8], the economic reform after the 2011 Nigeria's general elections amongst others. However, failure to account for structural breaks can produce misleading results which may lead to inaccurate inference and policy implication[9].

In order to carry out our econometric analysis, we first applied two set of unit root tests of which one considers the presence of structural break while the other does not. After getting our results from the two set of unit root tests, we applied two set of co-integration analysis of which one considers the presence of structural break while the other does not. We then perform a causality test for the short-run and long-run relationships among the variables.

The rest of this study is organized as follows. Section 2 gives some background study on related works of literature that focused on Nigeria's case. Section 3 describes the methodology and data used in the analysis. Section 3 presents the empirical results while Section 5 gives the policy implication and conclusion of our paper.

II. BACKGROUND STUDY

The relationship between energy and electricity consumption, CO2 emission economic growth has been extensively researched in energy economic literature. The oil shock of the 1970s leads to the rapid increase in studies of energy-related economic variables and economic growth in various countries, especially energy resource exporting countries. In contrast, two types of energy economy exist in the world; a growth-led-energy economy and energy-led-growth economy. A growth-led-energy economy is not affected by the global fluctuation in oil price, and the increase in the country's economic growth stimulates an increase in energy consumption.

On the other hand, an energy-led-growth economy may be affected by the fluctuation in the global oil price, and the rise in energy consumption leads to an increase in economic growth. The hypothesis implies that in a growth-led-energy economy, the direction of causality moves from economic growth to energy consumption while in an energy-led-growth economy, a causal direction from energy consumption moves to economic growth [5].

Energy is vital to the survival of an economy while its consumption is an important contributor to economic development. The efficient utilization and development of a nation's energy resources are of great importance to the

[1] http://pages.stern.nyu.edu/~nroubini/papers/OilShockRoubiniSetser.pdf

[2] http://www-personal.umich.edu/~lkilian/arre083113_cepr.pdf

[3] http://archive.lib.msu.edu/DMC/African%20Journals/pdfs/social%20development/vol7no1/jsda007001003.pdf

[4] http://nigerianwiki.com/wiki/June_12_election

[5] See[48].

[6] https://fas.org/sgp/crs/row/IB98046.pdf

[7] http://www.cenbank.org/OUT/SPEECHES/2004/Govadd-6Jul.pdf

[8] http://www.imf.org/external/pubs/ft/weo/2008/update/02/pdf/0708.pdf

[9]. The importance of this study cannot be over-emphasize due to the issue of climate change as a matter of global and national discourse and concern. It's in-line with best international practice, as-well-as economic policy decisions taken by government which seeks a sustainable development.

progress and well-being of the consuming populace. In Nigeria, a large energy demand-supply gap exists due to lack of adequate and efficient management of the energy sector. Although as an oil and gas exporting country, Nigeria is still lacking behind in terms of adequate supply of energy resources to the domestic consumers while electricity supply is still in its epileptic state [10]. It has resulted in the increase in various literature investigating the relationship between oil, gas, electricity and energy consumption, CO2 emissions and economic growth in Nigeria.

Nigeria as an energy exporting country may be affected by fluctuations in oil prices, economic crisis, reforms, changes in energy regulation and policies. It is, however, important to consider the possibility of structural changes when investigating the direction of the relationship between economic growth and other economic variables such as energy consumption, electricity consumption, oil consumption, gas consumption, etc.

Previous studies on the relationship between energy consumption, CO2 emission, and economic growth has shown conflicting results. Early studies include [6] who investigated the causal relationship between energy consumption and economic growth. His result revealed that there exist a simultaneous causal relationship between energy consumption and economic growth in Nigeria, and implication from the study was that without the reduction in energy supply deficit, the economic growth and development of Nigeria will be hindered.

A modified version of Granger causality (Toda and Yamamoto, 1995) and cointegration test was used by [7] to investigate the relationship between electricity consumption and economic growth in 17 African countries including Nigeria. His result showed that Nigeria had a positive unidirectional causality running from economic growth to electricity consumption. The implication of the study was for the formulation of energy efficiency policy since economic growth caused greater demand for electricity consumption.

The relationship between energy consumption and economic growth was investigated by [8] using annual time series from 1970-2005. He was the first to apply the Bond testing approach to cointegration was through the Autoregressive Distributed Lag (ARDL) procedure. His study disaggregated energy consumption into oil, gas and electricity consumption. The result showed that causality ran from oil consumption to economic growth, gas consumption caused economic growth with no feedback and no causal relationship between electricity consumption and economic growth. The cointegration result revealed no long run relationship between gas consumption and economic growth, and between electricity consumption and economic growth. This result agrees with [9] study which investigated energy consumption was disaggregated into coal, electricity, oil consumption and economic growth. He applied the Hsiao's Granger causality, and the result showed that energy consumption leads to economic growth. The policy implication suggested an energy enhancement policy which will improve the economic growth of Nigeria.

The study by [10] follows the same suit as [8,9] previously mentioned. Appling the cointegration technique, [10] investigated the relationship between crude oil, electricity, coal consumption and the Nigerian economic performance. The result showed a positive relationship between energy consumption and economic growth. They suggested that an increase in energy consumption was a strong determinant of Nigeria's economic growth. Similarly, [11] investigated the relationship between electricity consumption and economic growth from 1979-2008. The study found the existence of Granger causality which runs from economic growth to electricity consumption without any feedback, and this was a similar result obtained by [8].

Contrary to some results obtained by [8, 9, 10, 11], [12] analyzed the causality between GDP and some primary sub-components of energy consumption in Nigeria. Their result showed a unidirectional causality from electricity consumption to GDP on the short and long run. A unidirectional causality was discovered from gas consumption to GDP on the short-run and a bidirectional causality between the variables on the long-run. No causality was found between oil consumption and GDP in the short-run while a unidirectional causality from oil consumption to GDP was found in the long-run.

Applying the same method as [8] but including coal consumption, [13] examined the impact of energy consumption on economic growth in Nigeria by applying the ARDL approach to cointegration analysis. The result showed a long-run relationship between energy

[10] The current status of power generation in Nigeria presents challenges such as inadequate generation availability, delayed maintenance of facilities, insufficient funding of power stations, obsolete equipment, tools, safety facilities and operational vehicles, obsolete communication equipment, lack of exploration to tap all sources of energy from available resources and low staff morale[49,50, 51,52].

consumption and economic growth. Coal consumption was positive but statistically insignificant while petroleum consumption and electricity consumption had positive and statistically significant for economic growth. It contradicts the results obtained from [8] where no relationship was observed between electricity consumption and economic growth.

Appling a Multivariate Vector Error Correction Model (VECM) framework, [14] analyzed the long-run and causal relationship between electricity consumption, CO2 emissions and economic growth in Nigeria. Their result showed that in the long run, economic growth is associated with the increase in carbon emission and an increase in electricity consumption leads to an increase in carbon emissions. The Granger causality from their result showed a unidirectional causality which ran from economic growth to carbon emissions. No causality was found between electricity consumption and economic growth in Nigeria. This study was one of the pioneering studies to investigate the relationship between CO2 emissions and economic growth.

The long run relationship and direction of causality between energy consumption and economic growth were analyzed by [15], and the study considered financial development, monetary policy rate and consumer prices from 1971-2010. Their result showed no causal relationship between energy consumption and economic growth and no long run relationship between the two variables but on the short-run, it was positive and significantly influenced output growth. The study was in contradiction with previous studies [8,9,10] but agreed with [12]. It may be due to the consideration of financial development, monetary policy rate, and consumer prices. The study concluded that in the long run, energy consumption may not enhance the Nigerian economic growth but may improve it in the short-run.

An examination of the causal relationship between energy consumption and Nigeria's national income from 1990-2010 was carried out by [16]. They applied the Pearson correlation coefficient to determine the nature of the relationship between the two variables while Granger causality was used to identify the direction of the relationship. Their result showed a strong positive relation between energy consumption and national income. The linkages between electricity consumption and economic growth in Nigeria was investigated by [17] who applied the Vector Error Correction Model (VECM). The result of the short run and long run showed the existence of a causal flow from electricity consumption to economic growth. The paper further urged the government and policy makers to improve on the electricity generation in Nigeria to enhance economic growth.

In a related study to [17], [18] examined the relationship between electricity consumption and economic growth by applying the Error Correction Model (ECM) and Granger causality test for the time series data from 1971-2012. Their result showed that an increase in electricity consumption is a leading indicator of economic growth. The causality of energy consumption and economic growth were investigated by [19] who used time series data from the period of 1980-2012. They employed the Vector Auto Regressive (VAR) and Error Correction Model (ECM) to test the causality between the two variables. Their result showed a positive relationship between energy consumption and economic growth. No causality was found in the short run between the two variables in the short-run, but an unidirectional causality was discovered in the long-run that flow from economic growth to energy consumption. They suggested an energy conservation policy that will not affect the economic growth of Nigeria.

The studies reviewed and many others not mentioned in this paper had conflicting results and did not consider the presence of structural breaks in their data sets which may invalidate their results. [20] had clearly stated that some econometric analysis may yield misleading results if the fail to consider the presence of structural breaks. [21] also agrees with [20] in his study in which he investigated the long and short run causality between economic growth and energy consumption in Saudi Arabia by applying the [22] cointegration procedure and ECM. His research considered the presence of structural breaks, unlike previous studies that investigated the relationships among the economic variables in Saudi Arabia.

We, therefore, distinguish our paper from earlier works on energy consumption, CO2 emissions and economic growth in Nigeria by considering the effect of structural breaks while using updated data sets from 1980 to 2012. The next section describes that methodology and data used in this paper.

III. METHODOLOGY AND DATA

According to the literature on the long run relationship between economic growth and energy consumption, the empirical model can be written as;

$$y_t = y + ax_t + \varepsilon_t \quad (1)$$

Where y is the GDP and x is the energy consumption, while ε_t is the error term. We employ the annual time series data of Gross Domestic Product (hereafter, GDP), energy consumption (hereafter, En_cons), electricity consumption (hereafter, Elect_cons), oil consumption (hereafter, Oil_cons), gas consumption (hereafter, Gas_cons), CO2 emissions from electricity generation (hereafter, CO2_elect) and CO2 intensity (hereafter, CO2_inten).

This study uses annual time series data for the period of 1980-2012 (33 years) and is expressed in their logarithm terms. GDP data is expressed in constant 2005 US$, En_cons and Oil_cons were expressed in kg of oil equivalent per capita, Elect_cons is expressed in kilowatt hour, Gas_cons is expressed in million tons of oil equivalent, CO2_elect is expressed in million metric tons while CO2_inten is expressed in kg per kg oil equivalent energy use. The data for GDP were retrieved from the Central Bank of Nigeria Annual Statistical Bulletin [23]. Data for En_cons and Elect_cons were retrieved from the International Energy Agency [24]. Data for CO2_elect and CO2_inten were obtained from the World Development Indicators produced by the World Bank [25], Oil_cons and Gas_cons were obtained from the US Energy Information Administration [26]. The summary of the descriptive statistics are shown in Table 1 and the econometric software used for all the analysis in this study was the STATA 12[11].

Table 1. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Year	33	1996	9.66954	1980	2012
GDP	33	9.09E+10	1.15E+11	1.58E+10	4.61E+11
En_cons	33	84075.29	20529.4	52459.88	120018.4
Elect_cons	33	1.17E+10	5.85E+09	3.84E+09	2.63E+10
CO2_elect	33	11.92061	3.821687	5.1	19.15
CO2_inten	33	0.8527273	0.2387896	0.45	1.3
Oil_cons	33	3.26E+07	6808935	2.38E+07	4.36E+07
Gas_cons	33	5.24E+09	2.62E+09	9.83E+08	1.13E+10

The empirical steps that were taken to investigate the causality between our variable are as follows; the first step will perform a unit root test on all the variables to determine their order of integration. The second phase will investigate the long-run relationship between the variables by applying the cointegration technique. The third step involves the application of Granger causality to determine the short and long run causality relationship among the variables.

Nigeria as an energy-led-growth economy which depends heavily on energy consumption will be prone to the global oil and gas prices which can create structural breaks. Elect_cons and CO2_elect (and CO2_inten) could also be affected by the change in government policies, reforms, and economic activities. As previously stated in Section 2, previous studies that investigated the relationships among the variables in our study failed to consider the presence of structural breaks which may lead to distorted results. An increase in oil prices has a higher impact in an oil exporting country than a decrease in oil prices as pointed out by [27].

3.1. Unit Root Test without Structural Breaks

Usually, time series data are non-stationary in levels and hence when applied to regression analysis, they yield contradicting or unreliable results. However, if the time series data are non-stationary, the first differencing method is used to make the series stationary. We applied two methods of unit root test which are the Augmented Dickey-Fuller [28] (hereafter, ADF) and Phillips-Perron [29] (hereafter, PP) test with the regression equation shown in Equation 2 and 3. The ADF test was performed using the regression equation as follows;

$$\Delta ht = \emptyset_o + \emptyset_{1t} + ph_{t-1} + \sum_{t-1}^{k} \Omega_i \, \Delta h_{t-1} + u_{5t} \qquad (2)$$

Where Δh_t denotes the first difference of the series h_t, k denotes the lag order and *t* denotes time. The ADF equation (Equation 2) is specified with intercept term and time trend.

On the other hand, the PP test can be performed by the Ordinary Least Square (hereafter, OLS) regression which is written as follows;

$$h_t = \Psi_0 + \Psi_1 h_{t-1} + \Psi_2 \left[t - \frac{T}{2}\right] + u_{6t} \qquad (3)$$

Where Ψ_0, Ψ_1 and Ψ_2 denotes the conventional OLS regression coefficients. The unit root hypothesis to be tested is $H_0{:}\, \Psi_1 = 1$ and $H_0{:}\, \Psi_1 = 1, \Psi_2 = 0$. For the lag order determination, we employed the Akaike's Information Criterion (AIC) for all the variables in our study, while the Mackinnon's approximation [30] P-value are written in the bracket.

[11]StataCorp. 2011. Stata Statistical Software: Release 12. College Station, TX: StataCorp LP.

3.1.1. Unit Root with Structural Breaks

To conduct the unit root test with structural breaks, we employ the zivot and andrews [31] (hereafter, za) test to determine the order of integration. ZA modified and developed a version of Perron [20] test which in turn employed an ADF type of unit root testing strategy [32-33]. Three models were developed by ZA to test for unit roots; Model A (Shift in the intercept), Model B (Shift in the slope) and Model C (Shift in the intercept and slope). Meanwhile, [21] citing [34] suggested that the application of Model A instead of Model C may lead to a substantial power loss if the break occurs in Model C. But a minimal loss of power occurs when a break occurs in Model A when Model C is used. A similar study carried out by [35] also applied the ZA test for unit root in Saudi Arabia. The ZA [36][12] test for unit root Models are of the equations 4 to 6 as follows;

Model A:

$$y_t = \alpha_o + \alpha_1 DU_t + \beta t + \rho y_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta y_{t-i} + \varepsilon_t \quad (4)$$

Model B:

$$y_t = \alpha_o + y DT_t + \beta t + \rho y_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta y_{t-i} + \varepsilon_t \quad (5)$$

Model C:

$$y_t = \alpha_o + \alpha_1 DU_t + y DT_t + \beta t + \rho y_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta y_{t-i} + \varepsilon_t \quad (6)$$

Where DU_t denotes the intercept dummy variable for the mean shift, DT_t is an indicator variable for trend shift, $DU_t = 1$ and $DT_t = t - TBift > TB$ and Zero (0) otherwise. The first difference operator is denoted as Δ.The time the structural breaks occurs is represented by TB while the date of a structural break is identified through the smallest t-statistics. The index of time is represented as $t = 1, \ldots \ldots, T$ while the white noise disturbance is denoted as ε_t .

[12] A more detailed explanation of the Zivot and Andrews [36] unit root models can be found in [34].

Following [34], [35] and [21], we apply Model C, which examines the null hypothesis of a unit root against the alternative trend stationary process with a one known structural break. Just as in the unit root without structural breaks, the lag order determination is done by the AIC for all variables.

3.2. Cointegration Analysis

The Johansen trace test was proposed by Johansen [37-39] to identify the presence of cointegration among variables. The Johansen trace test for the existence of cointegration and some cointegrating vectors are based on the specification given below;

$$y_t = A_1 y_{t-1} + \cdots \ldots \ldots \ldots . + A_p y_{t-p} + B x_t + \varepsilon_t \quad (7)$$

Where y_t is a K-vector non-stationary I(1) variables (i.e. GDP, En_cons, Elect_cons, Oil_cons,CO2_elect and CO2_inten in this study); x_t is a d-vector of deterministic variables, ε_t is a vector for disturbances. Thus, Equation 7 can be written as;

$$\Delta y_t = \prod y_{t-1} + \sum_{i=1}^{\mathcal{P}-1} \Gamma_i \Delta y_{t-1} + B x_t + \varepsilon_t \quad (8)$$

Where: $\prod = \sum_{i=1}^{\mathcal{P}} A_i - I \; and \; \Gamma_i = \sum_{j=i+1}^{\mathcal{P}} A_i$

In the interpretation theorem of Granger, if the coefficient matrix, $\prod$, has a reduced rank, $r < k$, then there exist $k \times r$ matrices $\alpha and \beta$ each with the rank r such that $\prod = \alpha\beta^1 and \beta^1 y_t$ are stationary. Where r represents the number cointegration relations and β represents the cointegrating vector, α represents the adjustment parameters in Vector Error Correction Model (VECM). The matrix $\prod$, is estimated by the Johansen trace test from an unrestricted Vector Autoregressive (VAR) model and also test if the restrictions suggested by the reduced rank of $\prod$, could be rejected [39].

3.2.1. Gregory and HensenCointegration Test

According to Gregory and Hensen [22] (hereafter, GH), various researchers begin cointegration analysis with the usual ADF test, proceeded only if the statistics reject the null of no cointegration. But if the model is cointegrated with a one-time regime shift in the cointegrating vector, the null may be rejected by the standard ADF test which will lead the research to negatively conclude that there is no long-run relationship. GH [22] citing [40] proved that in the presence of structural break, conventional ADF test falls sharply.

The cointegration test modified by GH [22] is an extension of the residual-based test which observes the presence of a one-time unknown structural break in the intercept alone or both intercept and coefficient vector. In these test, the null hypothesis is that there is no cointegration with a structural break against the alternative which is a cointegration with a structural break.

GH [22] proposed three models[13]Which are; level shift (C) which contains an intercept before the shift as shown below;

$$y_{1t} = \mu_1 + \mu_2\varphi_{tT} + \alpha^T y_{2t} + \varepsilon_t \quad (9)$$

The next model was the level shift with trend (C/T) as shown below;

$$y_{1t} = \mu_1 + \mu_2\varphi_{tT} + \beta t + \alpha^T y_{2t} + \varepsilon_t \quad (10)$$

The last model allows the slop vector to shift as well which will enable the equilibrium ratio to rotate as well as shift parallel. The model is called the regime shift (C/S) and is shown below;

$$y_{1t} = \mu_1 + \mu_2\varphi_{tT} + \alpha^T y_{2t} + \alpha^T y_{2t}\varphi_{tT} + \varepsilon_t \quad (11)$$

Where y is the observed data and μ_1 and μ_2 represent the intercept before the shift and the change in the time of shift; φ[14] Is the dummy variable that captures structural change; 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 (GDP) while Y_{2t} is a vector of independent variables (En_cons, Elect_cons, Oil_cons, Gas_cons, CO2_inten and CO2_elect). The appropriate methods of testing the null hypothesis of no co-integration are residual-based and are obtained when Equation 9-11 are estimated using the ordinary least square and the unit root tests are applied to the regression errors (GH, 1996).

GH [22] also proposed three test statistics and they are as follows;

$$Z_a^* = inf_{t\varepsilon T} Z_\alpha(t)$$

$$Z_t^* = inf_{t\varepsilon T} Z_t(t)$$

$$ADF^* = inf_{t\varepsilon T} ADF(t)$$

Equation 12 and 13 are modified versions of [41] while equation 12 is the modified version of Engle and Granger [42]. The breakpoint is the smallest value of the three test statistics (Equation 12-13) because according to GH [22], the small value of the test statistics constitutes evidence against the null hypothesis. The modified Mackinnon[15] Critical values were applied rather than the critical values which were used in [42].

3.3. Causality Test

Engle and Granger [42] developed two-step test that could be used to identify the short run and long run causality. The Granger causality will be used to identify the direction of causality between our variables through the following steps; the first step is to estimate the residuals from the long run relationship while in the second steps, we will add the residual as a variable on the right-hand side in the Error Correction Model (ECM). The ECM can be written as follows;

$$\Delta y_t = y_1 + \sum_{i=1} \delta_{1j}\, y_{t-1} + \sum_{j=0} a_{1i}\, x_{t-j} + \theta_1 ECT_{t-1} + \varepsilon_{1t} \quad (15)$$

$$\Delta x_t = y_2 + \sum_{i=0} \delta_{2j}\, y_{t-1} + \sum_{j=1} a_{2i}\, x_{t-j} + \theta_2 ECT_{t-1} + \varepsilon_{2t} \quad (16)$$

Where y_t represents GDP and x_t represents En_cons (it also represents Elect_cons, Oil_cons, Gas_cons, CO2_elect, and CO2_inten). ECT_{t-1}represents the error correction term that is devised from the long run cointegration relationship and measures the magnitude of past disequilibrium. The adjustment coefficient θ represents the derivation of the dependent variables from the long run equilibrium. $\varepsilon_{1t} and \varepsilon_{2t}$represent serially uncorrelated error terms.

The ECM determines both the short run and long run causality in the following ways;

The short run causality is determined by testing for the joint significance of the coefficients of the independent variables;

[13] See Gregory and Hensen (1996) for more explanation of the three models.

[14] $\varphi_t - \left[\frac{0\ if\ t\leq(nT)}{1\ if\ t>(nT)}\right]$ Where the unknown parameter $T \in (0,1)$ implies the timing of the break point, and (nT) represents the integer part.

[15] Can also be found in MacKinnon, J. G. (2010). Critical values for cointegration tests (No. 1227). Queen's Economics Department Working Paper.

$H_0: a_{1i} = 0\ and H_0: \delta_{2j} = 0$ for all $i and j$ in equation 15 and 16.

The long-run causality is determined by testing for the significance of the speed of the adjustment coefficient θ which indicates that the long-run equilibrium relationship is directly pulling the dependent variable, thus;

$H_0: \theta_1 = 0\ and H_0: \theta_2 = 0\ inequation$ 15 and 16.

IV. EMPIRICAL RESULTS

4.1 Unit Root Test Results

We employed two set of the unit root; the first was the conventional unit root tests which included the ADF and PP test to identify the stationary relation of the variables. The results are presented in Table 2 in both the levels and first difference for all the variables in this study.

The result shows that all the variables in the test except Oil_cons are non-stationary according to their levels (unit root), but stationary in first difference. Due to the stationary form of Oil_cons, we dropped the variable from our analysis and moved on to test the other variables for cointegration over the sample period. We should, however, note that the first unit root test (i.e. ADF and PP test) does not consider the possibility of structural breaks which may lead to distorted results when we accept the null hypothesis of the unit root.

Table 2. ADF and PP unit root test results.

Variables	ADF		PP		Unit root
	Level	1st Difference	Level	1st Difference	
GDP	1.641 (0.9980)	-5.538 (0.0000)	2.245 (0.9989)	-5.593 (0.0000)	I[1]
En_cons	0.594 (0.9875)	-6.280 (0.0000)	0.925 (0.9934)	-6.417 (0.0000)	I[1]
Elect_cons	1.017 (0.9944)	-6.831 (0.0000)	1.744 (0.9982)	-6.750 (0.0000)	I[1]
Oil_cons	-5.582 (0.0000)	-8.503 (0.0000)	-5.615(0.0000)	-8.833 (0.0000)	I[O]
Gas_cons	-1.770 (0.3957)	-4.688 (0.0001)	-1.774(0.3934)	-4.618 (0.0001)	I[1]
CO2_elect	-1.026 (0.7437)	-6.703 (0.0000)	-0.843(0.8060)	-6.866 (0.0000)	I[1]
CO2_inten	-2.352 (0.1556)	-6.199 (0.0000)	-2.349 (0.1568)	-6.201 (0.0000)	I[1]

Mackinnon's approximate p-value are in parenthesis.

The second set of unit root test was the ZA test which considers the presence of structural breaks and the results are shown in Table 3. As can be seen from Table 2, various structural breaks (break date) can be seen in both the level and first difference. GDP had a structural break in 1993 and this was the year that the Nigeria Civilian President Ernest Shonekan was overthrown through a military coup by General Sani Abacha (late) following various political controversies.

Table 3. ZA unit root test results.

Variables	Level	Break data	1st Difference	Break date	Order
GDP	-3.748 (1)	1993	-7.178 (0)***	1995	I[1]
En_cons	-3.927 (0)	2001	-6.006 (0)***	1996	I[1]
Elect_cons	-4.666 (0)	1996	-4.763 (2)	2002	I[0]
Oil_cons	-13.385 (2)***	2007	-22.054 (2)***	2006	I[0]
Gas_cons	-5.155 (0)**	2006	-5.506 (1)**	2003	I[0]
CO2_elect	-4.918 (1)	2000	-5.470 (0)**	1999	I[1]
CO2_inten	-4.694 (1)	2004	-6.802 (0)***	2007	I[1]

, * represents 5%, 1% significance levels respectively. Lag numbers are in parenthesis.

En_cons had a structural break in 2001 which was two years after the new civilian president returned to power and began various energy sector development. The Nigerian civilian government in 1999 was faced with various challenges coming from the power sector especially electricity generation. The president in a bid to respond to the situation undertook an aggressive rehabilitation of the power infrastructure between 1999 and 2004 which was referred to as the Infrastructural Rehabilitation Phase and was part of the Electric Power Sector Reform (EPSR) Act. This saw a boost in the electricity generation capacity in 2004 by the opening of gas power stations in Nigeria by the National Integrated Power Project (NIPP) [43].

From Table 3, the ZA test result shows that GDP, En_cons, and CO2_elect series are in the order I[1] while Elect_cons, Oil_cons, Gas_cons and CO2_inten are in the order I[0]. The ZA unit root test allows us to proceed with variables that from the order I[1] while we drop the variable with the order I[0] from the GH test which follows in the next section. We also performed the Johansen test on all the variables except Oil_cons to compare the two cointegration test.

4.2. Cointegration Test Results

Just as in the last section, we conducted two set of cointegration test on our variables, the first was the Johansen cointegration test, and the result is shown Table 4. From the result, we can accept the hypothesis r_0=0 of no cointegrating vector in both the 5% and 1% significance level (critical values) but within H_0:r_0≤1, the eigenvalue and trace statistics are below the 5% and 1% critical values, and so the null hypothesis is accepted in all the variables except for GDP and CO2_inten.

Table 4. Johansen cointegration test results.

Variables	Number of cointegration	Trace test				
		Eigenvalue	Trace Statistics	5% critical value	1% critical value	Result
GDP and En_cons	None	0.46129	19.3037	15.41	20.04	Reject
	At most one	0.00411	0.1276*	3.76	6.65	Accept
GDP and Elect_cons	None	0.40106	16.8151	15.41	20.04	Reject
	At most one	0.06503	1.9499*	3.76	6.65	Accept
GDP and Gas_cons	None	0.56603	25.9066	15.41	20.04	Reject
	At most one	0.00902	0.0286**	3.76	6.65	Accept
GDP and CO2_elect	None	0.44228	17.8708	15.41	20.04	Reject
	At most one	0.01173	0.3539*	3.76	6.65	Accept
GDP and CO2_inten	None	0.30674	13.3706**	15.41	20.04	Accept
	At most one	0.06290	2.0138	3.76	6.65	Reject

* represents significance at 1%, ** represents significance at 5%.

Since GDP and CO2_inten have no cointegration, we difference the variables and set up a Vector Autoregressive (VAR), and the result is shown in Table 5. From Table 5, it can be obsessed that an effective change in GDP will lead to a change in CO2_inten. But a change in CO2_inten will not cause a change in GDP. From the P-value, unidirectional causality was found to be present from GDP to CO2_inten at 95% confidence interval.

Table 5. Vector Autoregressive result.

Dependent Variable	Explanatory variable	z	P> $\|z\|$	95% Confidence interval
dGDP	dGDP	0.08	0.937	-0.2999156 – 0.3252563
	dCO2_inten	-3.46	0.001**	-1.082984 – 2.997222
dCO2_inten	dGDP	2.07	0.038	0.0146692 – 0.5344823
	dCO2_inten	0.19	0.847	-0.2934746 – 0.3577862

** represents significance at 10%.

The second set of cointegration test was the GH test which considers the presence of a one-time structural break. Two researchers, [20] and [44] expressed the importance of structural breaks in both unit root test and cointegration of which if ignored, may yield inaccurate cointegration results. The GH cointegration results are presented in Table 6, 7, 8 and 9.

Table 6. GH test result for GDP-En_cons.

Variable	Model	Za*	Break	Zt*	Break	ADF*	Break
GDP-En_cons	C	-12.37	2004	-3.20	2004	-2.89	1989
	C/T	-15.95	2002	-3.16	2002	-3.11	2002
	C/S	-14.34	1996	-3.14	1996	-3.04	2000

From the result, the null hypothesis of no cointegration is accepted for the existence of no single cointegration among the three models (C, C/T, and C/S) in GDP-En_cons, En_cons-GDP, and GDP-CO2_elect (see Table 6, 7 and 9). Meanwhile, the null hypothesis of no cointegration is rejected for the existence of one cointegration with a one-time unknown structural break in C/T model which is a level shift with the trend (Table 8) for GDP-CO2_inten.

Table 7. GH test result for En_cons-GDP.

Variable	**Model**	**Za***	**Break**	**Zt***	**Break**	**ADF***	**Break**
En_cons-GDP	C	-14.05	1988	-3.56	1988	-3.39	1989
	C/T	-23.98	2000	-4.41	2000	-4.20	2007
	C/S	-21.52	1990	-3.93	1990	-3.93	1990

From Table 8, the breakpoints are observed to be consistent across the three models. The break date in Table 8 which 2006 coincide with a rapid increase in fuel subsidy which was US$2.03 billion (1.4% of GDP) and this rose to US$2.3 billion in 2007. The increase in the fuel subsidy was due to the rising oil price and depreciating exchange rate. The effect of this rapid rise in fuel subsidy payment by the Nigeria government leads to an exponential growth in domestic oil consumption as the low price did not reflect the cost of consumption.

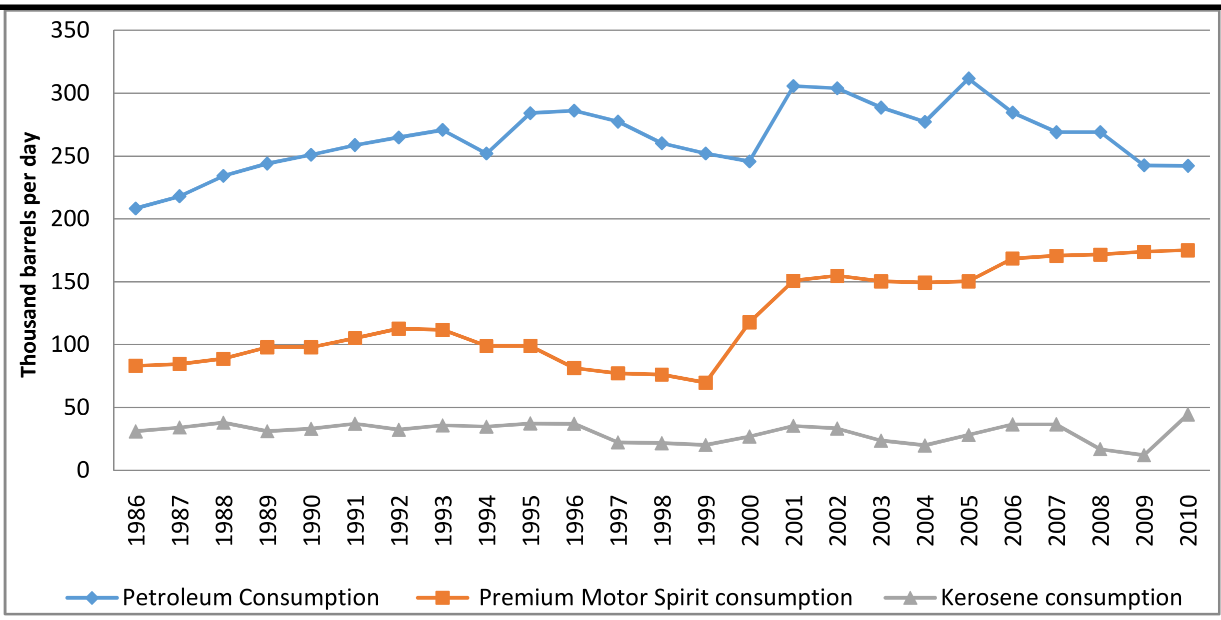
Table 8. GH test result for GDP-CO2_inten.

Variable	**Model**	**Za***	**Break**	**Zt***	**Break**	**ADF***	**Break**
GDP-CO2_inten	C	-15.25	2005	-3.24	2005	-3.04	2006
	C/T	-16.26	2007	-3.63	2007	-4.72*	2006
	C/S	-15.28	2006	-3.21	2006	-3.09	2006

In other words, fuel was cheap and affordable to Nigerians who increased their usual consumption rate, which in turn affect the CO2 emission intensity. Figure 1 shows the Total consumption of petroleum products in Nigeria. The consumption of the petroleum products can be observed to have increased from 2006, and the structural change corresponds with our result in Table 8.

Table 9. GH test result for GDP-CO2_elect.

Variable	**Model**	**Za***	**Break**	**Zt***	**Break**	**ADF***	**Break**
GDP-CO2_elect	C	-15.34	2002	-3.77	2002	-2.85	2002
	C/T	-20.71	2002	-3.57	2002	-3.51	2002
	C/S	15.61	1992	-3.08	1992	-3.03	1992



Source: Ref. [26]

Fig.8: Total consumption of petroleum products in Nigeria.

4.3. Granger Causality Test Result

The variables that show evidence of cointegration in Section 4.2 were further investigated for their short-run and long-run causal relationships. Cointegration signifies the existence of causality among the variables but does not indicate the direction of the causal relationship. Therefore, if there is, at least, one cointegration between the variables, there should also be unidirectional or bidirectional causality between the variables [45].

Table 10 and 11 shows the result of the Granger causality test for the short and long run causality respectively. From the short-run causality (Table 9), bidirectional causality exists between GDP and En_cons, which is significant at 1% for GDP to En_cons and 5% for En_cons to GDP. A similar case was observed in GDP and Gas_cons, which is also bi-directional with 1% significance level for both GDP to Gas_cons and Gas_cons to GDP.

Table 10. Short run causality results.

Null hypothesis	**F-statistics** (x^2)	**Probabilities** $(Prob > x^2)$	**Result**
GDP does not Granger cause En_cons	0.067654	0.0019	Reject*
En_cons does not Granger cause GDP	0.656553	0.0461	Reject**
GDP does not Granger cause Elect_cons	4.473208	0.1137	Accept
Elect_cons does not Granger cause GDP	0.387157	0.0414	Reject**
GDP does not Granger cause Gas_cons	1.676259	0.0011	Reject*
Gas_cons does not Granger cause GDP	0.275613	0.0047	Reject*
GDP does not Granger cause CO2_elect	1.887571	0.0023	Reject*
CO2_elect does not Granger cause GDP	0.002351	0.3245	Accept
GDP does not Granger cause CO2_inten	3.740367	0.0034	Reject*
CO2_inten does not Granger cause GDP	0.445972	0.1216	Accept

*,** represents 1% and 5% significant levels respectively.

A unidirectional causality was observed from Elect_cons to GDP, GDP to CO2_elect and GDP to CO2_inten at the significance level of 5%, 1%, and 1% respectively. While no causality was found from GDP to Elect_cons, CO2_elect to GDP and CO2_inten to GDP.

Table 11. Long run causality results.

Null hypothesis	**t-statistics (x^2)**	**Probabilities ($Prob > t$)**	**Result**
GDP does not Granger cause En_cons	0.093753	0.0014	Reject*
En_cons does not Granger cause GDP	0.091883	0.6599	Accept
GDP does not Granger cause Elect_cons	0.019282	0.0072	Reject*
Elect_cons does not Granger cause GDP	-0.230044	0.6417	Accept
GDP does not Granger cause Gas_cons	0.108856	0.0024	Reject*
Gas_cons does not Granger cause GDP	-0.349090	0.0079	Reject*
GDP does not Granger cause CO2_elect	0.106097	0.0362	Reject**
CO2_elect does not Granger cause GDP	-0.000478	0.2426	Accept

*,** represents 1% and 5% significant levels respectively.

For the long run causality (Table 11), a bidirectional causality exists between GDP and Gas_cons at 1% significance level in both directions. Unidirectional causality was observed to run from GDP to En_cons, GDP to Elect_cons and GDP_CO2_elect at a significance level of 1%, 1%, and 5% respectively. En_cons to GDP, Elect_cons to GDP and CO2_elect to GDP showed no causality.

V. DISCUSSION

From the results of this study, some implications could be drawn from it. The first is for energy economist and policymakers to consider structural breaks when analyzing time series data. The two cointegration result produced conflicting results which were because one examined the presence of structural breaks (GH test) while the other did not (Johansen test).

In the Johansen test, cointegration was discovered to exist among GDP and En_cons, GDP and Elect_cons, GDP and Gas_cons, GDP and CO2_elect, while none was found between GDP and CO2_inten. However, when we carried out the GH test, we found out that GDP and En_cons were not cointegrated the result of our earlier cointegration test (Johansen test).

GDP and CO2_elect showed no cointegration in the GH test but showed cointegration in Johansen test. In contradiction to the Johansen cointegration result, GDP was discovered to have cointegration with CO2_inten in the C/T model of the GH test and the breakpoint was consistent across the three models. The cointegration result implies that economic growth in Nigeria (GDP) does not have a long run relationship (not cointegrated) with energy consumption (En_cons) if we are to consider the presence of structural breaks. In other words, a change in GDP will not affect energy consumption and CO2 emission from electricity generation, but a change in GDP will affect CO2 emission intensity. Most oil and gas exporting countries have similar results, as was investigated by [46] for the case of Indonesia which shares several features with Nigeria.

Our result for cointegration for the variables using GH test is in contradiction with the studies carried out by [6-13, 15-17, 47] as well as other studies on economic growth, CO2 emission and energy consumption in Nigeria that are not mentioned in this study as of the time this analysis was carried out.

Moving to our causality results, a change in GDP will cause a change in energy consumption in the short and long run while a change in energy consumption will cause a change in GDP in the short-run but not in the long-run. The policy implication of these findings suggests that Nigeria should not implement energy conservation policies without considering the long-run effect on the country's economic growth. However, energy efficiency policies in the short and long-run should be considered as a move in the right direction. It is also essential for the formulation of an effective energy policy by the government that will guide the future energy demand to avoid policy conflicts.

The result for GDP and electricity consumption showed that a change in GDP will not affect electricity consumption in the short run but will in the long run while a change in electricity consumption will affect GDP in the short-run but not on the long-run. It implies that the government should do more in improving power generation in the country to meet the growing demand which will also increase Nigeria's economic growth in the short-run. It is in line with the studies carried out by [7] and [11] but contradicts [18].

Short-run and long-run was discovered to run in both ways (bidirectional) for GDP and gas consumption. This implies that a change in the two variables will affect each other in the short and long run. Therefore, the policy implication suggests that efforts should be made by the government to improve gas development in the country since its improvement will improve the economic growth of Nigeria in the short and long run.

A change in economic growth was observed to cause a change in CO2 emissions from electricity generation in the short and long-run, but a change in CO2 emissions from electricity generation will not cause a change in economic growth. It implies that Nigeria continues to expand in economic development which will increase economic activities that involve the consumption of electricity, more CO2 emission will be released which will contribute to the growing GHG emission. It can be addressed if efforts are made by the government and private investors to include more renewable electricity source to the country's electricity mix such as wind farms, solar farms and more hydropower station.

Economic growth and CO2 intensity showed a unidirectional relationship with causality running from economic growth to CO2 emission intensity. Since CO2 emission intensity affected by an increase in economic growth, policies should be put in to reduce the dependence of economic activities on emission generating energy source. In order words, alternative source of energy with low CO2 emission should be explored by the Nigerian government to address CO2 emission challenges without sacrificing the country's economic growth.

VI. CONCLUSION AND POLICY RECOMMENDATION

Nigeria as a party to the Kyoto Protocol is faced with the challenge of reducing CO2 emission either through efficient fossil fuel use with technology to reduce CO2 emission or the adaptation of renewable energy technology. The problem that arises is balancing fossil fuel consumption and reducing GHG emission in a way that it will not affect the country's economic growth.

This paper reinvestigated the relationship between CO2 emission, energy consumption and economic growth for the period of 1980 to 2012. Nigeria as an energy-led-growth economy is bound to be affected by oil price fluctuations in the global market which will likely create structural breaks in economic data.

Since previous studies have provided conflicting results without considering structural breaks, we applied two set of analysis in both the unit root test and cointegration test. In the unit root test, we used the standard Augmented Dickey-Fuller and Phillips-Perron test which does not consider the presence of structural breaks and the second type of unit root test was the Zivot and Andrews test.

In the cointegration test, we also employed two set of cointegration test; the first was the Johansen cointegration test which does not take into account the presence of structural breaks. The result showed that economic growth was cointegrated with energy consumption, electricity consumption, gas consumption and CO2 emission from power generation.

The second test was the Gregory and Hansen test which took into account the presence of structural breaks. The result showed that among all the variables in our study, only economic growth and CO2 emission intensity that were cointegrated. The structural break occurred in 2006 and was consistent with the three models. The breakpoint (2006) corresponds to the period of various energy sector reforms and the rapid increase in fuel subsidy which was due to increase oil prices and depreciating exchange rate. This result was in contradiction with our Johansen test result, as well as previous studies carried out by researchers who did not consider the importance of structural breaks in their analysis.

The last step in our analysis was to investigate the short-run and long-run causal relationships among variables from our two set of cointegration results. We employed the Granger causality test on our cointegrated variables for both the short and long run relationships. Our short-run result showed evidence of bidirectional causality in both economic growth and energy consumption, and economic growth and gas consumption.

A unidirectional causality ran from electricity consumption to economic growth, economic growth to CO2 emission intensity. On the long run, only economic growth and gas consumption had a bidirectional causal relationship. The unidirectional relationship ran from economic growth to energy consumption, electricity consumption and CO2 emission from power generation.

The policy recommendation that could be deduced from this study is that energy conservation policy should not be implemented in Nigeria without considering the short run effect on the country's economic growth. Instead, we recommend energy efficiency policies which will not affect economic growth and also an effective energy policy formulation.

On the long run, energy conservation policy should be formulated with no caution on the economic growth since our result found causality to run from economic growth to energy consumption in the long-run. Gas development both on the short and long should be intensified to improve gas consumption in Nigeria which will contribute to economic growth. It can be achieved by introducing and improving natural gas consumption in household, transport, agriculture and manufacturing sector of the economy.

Electricity rationing or conservation should not be considered as it affects economic growth in Nigeria. It is due to the causality which ran from electricity consumption to economic growth on the short-run. Nigeria should diversify its energy source to reduce CO2 emission from electricity generation and energy combustion (emission intensity), and our result shows causality running from economic growth to CO2 emission from both electricity generation and intensity.

Since Nigeria is blessed with an abundant amount of renewable energy resources such as solar, wind, hydropower and biomass, and improved utilization of these resources will improve the country's energy security and ensure sustainability as well as reduce GHG emission from fossil fuel use.

Further studies should focus on the effect of structural breaks in the relationship between energy consumption and economic growth in oil and gas exporting countries such as Organization of the Petroleum Exporting Countries (OPEC). This is because as these oil exporting countries depend heavily on oil export revenue, their economy will be exposed to oil price fluctuations which will result in structural breaks in their economic data. A time series analysis of these oil exporting countries may lead to distorted results and wrong policy formulation from the study.

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