Vol. 2(3), 84-94

Journal of Energy & Environmental Policy Options

Analyzing the Nexus between Energy Consumption, CO2 Emissions, and Economic Growth in Nigeria

Saratu Augusta Emodi[a]

Abstract

This study conducts a comprehensive analysis of the causal relationship between energy consumption, CO2 emissions, and economic growth in Nigeria over the period 1980-2020, considering the presence of structural breaks. Employing two sets of unit root tests—one accounting for structural breaks and the other not—the study provides valuable insights into the dynamics among these variables. The results of the Johansen test indicate cointegration between economic growth and various energy consumption metrics, including energy, electricity, and gas consumption, as well as CO2 emissions from power generation. However, the Gregory and Hansen test only identifies cointegration between economic growth and CO2 intensity, suggesting a more nuanced relationship between economic growth and environmental factors. Furthermore, the Granger causality analysis reveals bidirectional causality between GDP and energy consumption in the short run, with a unidirectional flow from GDP to energy consumption in the long run. Similarly, GDP and gas consumption exhibit bidirectional causality both in the short and long run, indicating a mutually reinforcing relationship between economic activity and gas consumption. In contrast, the relationship between electricity consumption and GDP shows mixed unidirectional causality in both the short and long run, highlighting the complexity of their interaction. Notably, the causality analysis indicates a unidirectional flow from GDP to CO2 emissions from power generation and intensity, underscoring the influence of economic growth on environmental outcomes. Based on these findings, the study offers several policy recommendations for Nigeria. Firstly, energy conservation policies should be implemented cautiously, considering their potential impact on economic growth. While conserving energy is important for environmental sustainability, overly restrictive policies may inadvertently hinder economic development. Secondly, the study suggests that gas development should be encouraged as part of Nigeria's energy strategy. Gas is a cleaner alternative to traditional fossil fuels and can contribute to reducing CO2 emissions without sacrificing economic growth. Additionally, diversifying Nigeria's energy mix can help mitigate CO2 emissions while supporting economic growth. Investing in renewable energy sources such as solar and wind power can further enhance energy security and sustainability.

Keywords: Energy Consumption, CO2 Emissions, Economic Growth
JEL Codes: Q43, O44, O55

1. INTRODUCTION

The urgency of addressing climate change and its impacts is increasingly evident, with countries like Nigeria facing significant challenges due to rising temperatures and sea levels (Clements & Practical, 2009). As a member of the UNFCCC, Nigeria is committed to international efforts to mitigate climate change and reduce carbon emissions. Climate change poses a threat not only to Nigeria but also to the broader African continent, with projections indicating potential flooding, economic disruptions, and environmental degradation (Clements & Practical, 2009). Rising temperatures and sea levels are key concerns, particularly for regions like the Niger Delta, which are vulnerable to extreme weather events and sea level rise. Global initiatives such as the Kyoto Protocol have sought to address climate change by promoting renewable energy sources and reducing reliance on fossil fuels. However, there is still much work to be done to achieve meaningful progress in combating climate change and its adverse effects. The need for concerted global action to mitigate climate change is paramount, as the impacts of climate change transcend national boundaries. By working together to reduce carbon emissions, promote sustainable development, and adapt to changing environmental conditions, countries can mitigate the worst effects of climate change and build a more resilient future for all.

The paper aims to re-examine the relationship between CO2 emissions from electricity and energy use intensity, energy and power consumption, and economic growth in Nigeria, considering the presence of structural breaks. Previous literature has investigated this nexus but yielded contradictory results. These studies typically employed conventional econometric techniques like unit root tests, cointegration analysis, and Granger causality tests. However, they overlooked the potential impact of structural breaks in energy consumption, particularly due to shifts from regulated to deregulated regimes. Structural breaks, such as those stemming from changes in energy policies, economic reforms, or global economic crises, can significantly influence energy consumption patterns. Failure to account for these breaks may result in misleading findings and

[a] College of Physical and Applied Science, Michael Okpara University of Agriculture, Umudike, Nigeria

erroneous policy recommendations. Therefore, this paper seeks to address this gap by incorporating structural break analysis into the investigation of the energy-emission-growth nexus in Nigeria. By doing so, it aims to provide more robust and accurate insights for policymakers and researchers. In our econometric analysis, we took a comprehensive approach by conducting two sets of unit root tests and cointegration analyses, each considering the presence of structural breaks and without. This dual approach allows us to capture the potential impact of structural breaks on the stationarity and long-term relationships among the variables. By conducting unit root tests, we assessed the stationarity of the variables under investigation, accounting for structural breaks that may occur due to significant events or policy changes over time. Subsequently, we performed cointegration analyses to explore the long-term relationships between the variables, considering both scenarios with and without structural breaks. Finally, to examine the causal relationships among the variables, we conducted causality tests for both short-run and long-run dynamics. This step helps us understand the direction and nature of causality between CO2 emissions, energy consumption, and economic growth, taking into account any structural breaks that may influence these relationships. By adopting this comprehensive approach, we aim to provide more robust and reliable insights into the complex interactions among CO2 emissions, energy consumption, and economic growth in Nigeria, considering the dynamic nature of the country's energy landscape and policy environment.

2. RELATED LITERATURE

The literature on the relationship between energy consumption and economic growth has delved into various dimensions, including the direction of causality and the impact of external factors like global oil prices. In an energy-led-growth economy, fluctuations in energy consumption are seen to influence economic growth, often driven by changes in global oil prices. Conversely, in a growth-led-energy economy, economic growth drives changes in energy consumption patterns (Abrokwah-Koranteng, 2013). Early investigations by Ebohon (1996) explored the causal relationship between energy consumption and economic growth, revealing a simultaneous causal relationship between the two in Nigeria. The study highlighted the hindrance to Nigeria's economic growth and development posed by the persistent energy supply deficit (Ebohon, 1996). Wolde-Rufael (2006) conducted a comprehensive analysis across 17 African countries, including Nigeria, using a modified version of Granger causality and cointegration tests to examine the relationship between electricity consumption and economic growth. The study found a positive unidirectional causality from economic growth to electricity consumption specifically in Nigeria. This result underscored the importance of formulating energy efficiency policies to manage the increasing demand for electricity consumption driven by economic growth (Wolde-Rufael, 2006).

In a similar vein, Omisakin (2008) investigated the relationship between energy consumption and economic growth in Nigeria using annual time series data spanning from 1970 to 2005. Omisakin (2008) introduced the Bond testing approach to cointegration through the Autoregressive Distributed Lag (ARDL) procedure. By disaggregating energy consumption into oil, gas, and electricity consumption, the study revealed a causal relationship from oil consumption to economic growth. However, gas consumption was found to lead to economic growth without feedback, and no significant causal link was observed between electricity consumption and economic growth. Contrary to expectations, the cointegration analysis indicated the absence of a long-run relationship between gas consumption and economic growth, as well as between electricity consumption and economic growth (Omisakin, 2008). Similarly, Omotor (2008) conducted a study that disaggregated energy consumption into coal, electricity, and oil consumption to explore their relationship with economic growth. Utilizing Hsiao's Granger causality test, the findings revealed that energy consumption preceded economic growth, underscoring the significance of implementing energy enhancement policies to bolster Nigeria's economic growth trajectory (Omotor, 2008). In a parallel investigation, Gbadebo and Okonkwo (2009) delved into the relationship between crude oil, electricity, and coal consumption and Nigeria's economic performance. Their analysis uncovered a positive association between energy consumption and economic growth, highlighting the pivotal role of heightened energy consumption in propelling economic expansion within Nigeria (Gbadebo & Okonkwo, 2009). Likewise, Emeka (2010) directed attention to the nexus between electricity consumption and economic growth spanning from 1979 to 2008. Through their examination, Granger causality was detected from economic growth to electricity consumption without reciprocal feedback, aligning with the conclusions drawn from Omisakin's study (Emeka, 2010).

Contrary to the findings of previous studies (Orhewere & Henry, 2011; Dantama et al., 2012), Orhewere and Henry (2011) conducted an analysis of the causality between GDP and specific primary components of energy consumption in Nigeria. Their investigation unveiled a unidirectional causality from electricity consumption to GDP in both the short and long run. Additionally, a unidirectional causality was observed from gas consumption to GDP in the short run, with a bidirectional causality between the variables in the long run. However, no causality was detected between oil consumption and GDP in the short run, while a unidirectional causality from oil consumption to GDP was identified in the long run. Using a similar methodology as Omisakin (2008) but incorporating coal consumption, Dantama, Abdullahi, and Inuwa (2012) explored the impact of energy consumption on economic growth in Nigeria. Employing the ARDL approach to cointegration analysis, their results indicated a long-run relationship between energy consumption and economic growth. Although coal consumption was positively associated with economic growth, the relationship was statistically insignificant. In contrast, both petroleum consumption and electricity consumption exhibited positive and statistically significant impacts on economic growth, contradicting the findings of Omisakin (2008), where no significant relationship was observed between electricity consumption and economic growth. Appling a Multivariate Vector Error Correction Model (VECM) framework, Akpan and

Akpan (2012) conducted an analysis of the long-run and causal relationship between electricity consumption, CO_2 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 CO_2 emissions and economic growth.

The long-run relationship and direction of causality between energy consumption and economic growth were analyzed by Abalaba and Dada (2013). Their study considered financial development, monetary policy rate, and consumer prices from 1971-2010. The results showed no causal relationship between energy consumption and economic growth, and no long-run relationship between the two variables. However, in the short-run, energy consumption positively and significantly influenced output growth. This finding contradicted previous studies (Omisakin, 2008; Omotor, 2008; Gbadebo & Okonkwo, 2009). An examination of the causal relationship between energy consumption and Nigeria's national income from 1990-2010 was carried out by Kabir, Zaku, and Tukur (2013). 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 results showed a strong positive relation between energy consumption and national income. The linkages between electricity consumption and economic growth in Nigeria were investigated by Njindan (2014), who applied the Vector Error Correction Model (VECM). The results 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 policymakers to improve electricity generation in Nigeria to enhance economic growth. In a related study to Njindan (2014), Okoligwe and Ihugba (2014) 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 results showed that an increase in electricity consumption is a leading indicator of economic growth. The causality of energy consumption and economic growth was investigated by Osundina, Kemisola, and Odukale (2014), 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 preceding studies, along with others not explicitly mentioned, have produced contradictory findings and generally overlooked the potential influence of structural breaks in their datasets, which could compromise the validity of their conclusions. Perron (1989) emphasized the significance of accounting for structural breaks in econometric analyses, warning that failing to do so might lead to erroneous outcomes. This sentiment was echoed by Banafea (2014) in a study examining the relationship between economic growth and energy consumption in Saudi Arabia. Banafea's research, which utilized the Gregory and Hansen (1996) cointegration approach and Error Correction Model (ECM), explicitly addressed the presence of structural breaks—a departure from prior studies in the Saudi context. Consequently, our study seeks to distinguish itself from earlier research on the nexus between energy consumption, CO_2 emissions, and economic growth in Nigeria by explicitly considering the impact of structural breaks while employing updated datasets spanning from 1980 to 2012. The subsequent section outlines the methodology and dataset employed in our analysis.

3. METHODOLOGY

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

$$y_t = y + ax_t + \varepsilon_t$$

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), CO_2 emissions from electricity generation (hereafter, CO2_elect) and CO_2 intensity (hereafter, CO2_inten).

This study uses annual time series data for the period of 1980-2020 and is expressed in their logarithm terms. GDP data is expressed in constant 2005 US$, En_cons and Oil_cons are expressed in kg of oil equivalent per capita, Elect_cons is expressed in kilowatt hours, Gas_cons is expressed in million tons of oil equivalent, CO2_elect is expressed in million metric tons, and 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 (Central Bank of Nigeria Annual Statistical Bulletin, 2013). Data for En_cons and Elect_cons were retrieved from the International Energy Agency (International Energy Agency Online Statistics Report). Data for CO2_elect and CO2_inten were obtained from the World Development Indicators produced by the World Bank (World Development Indicators, World Bank Databank), while Oil_cons and Gas_cons were obtained from the US Energy Information Administration (United States Energy Information Administration). The summary of the descriptive statistics is shown in Table 1. Typically, time series data exhibit non-stationarity in levels, and when utilized in regression analysis, they can produce inconsistent or unreliable outcomes. To mitigate this issue, if the time series data are non-stationary, the first differencing method is employed to render the series stationary. In our analysis, we utilized two methods of unit root testing:

the Augmented Dickey-Fuller (ADF) test proposed by Dickey and Fuller (1979), and the Phillips-Perron test introduced by Phillips and Perron (1988).

For unit root testing with structural breaks, we employed the Zivot and Andrews (ZA) test to ascertain the order of integration. Zivot and Andrews (2002) developed a modified version of Perron's test, which integrates an ADF-style unit root testing approach. This methodology ensures that structural breaks in the time series data are adequately addressed, thereby yielding more robust and reliable results (Dickey & Fuller, 1981; Said & Dickey, 1984). Zivot and Andrews (ZA) devised three models 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). Previous studies by Banafea (2014) and Sen (2003) have indicated that opting for Model A instead of Model C could result in a significant loss of statistical power if the break occurs in Model C. Conversely, if a break occurs in Model A while Model C is employed, the loss of power is minimal. The Johansen trace test, introduced by Johansen (1988), serves as a crucial tool in detecting the presence of cointegration among variables. According to Gregory and Hansen (1996), many researchers initially conduct cointegration analysis using the standard Augmented Dickey-Fuller (ADF) test. However, if the model exhibits cointegration with a one-time regime shift in the cointegrating vector, the null hypothesis may be incorrectly rejected by the standard ADF test, erroneously indicating the absence of a long-run relationship. Gregory and Hansen (1996), along with Gregory, Nason, and Watt (1996), illustrated that the conventional ADF test encounters significant shortcomings in the presence of a structural break. Engle and Granger (1987) devised a two-step test to discern short-run and long-run causality. Granger causality will elucidate the direction of causality between our variables through the following steps: in the first step, we estimate the residuals from the long-run relationship, while in the second step, we incorporate these residuals as a variable on the right-hand side in the Error Correction Model (ECM).

4. RESULTS AND DISCUSSION

The table 1 provides a comprehensive overview of various key variables related to economic activity, energy consumption, and environmental impact. Firstly, the Gross Domestic Product (GDP) variable, which serves as a measure of economic output, exhibits considerable variability, with a mean value of approximately 9.09E+10 and a wide range from 1.58E+10 to 4.61E+11. This indicates the diversity in economic sizes among the observed entities. Energy consumption (En_cons) and electricity consumption (Elect_cons) variables reflect the energy requirements within the observed entities. The mean energy consumption is approximately 84075.29, with a standard deviation of 20529.4, suggesting variations in energy needs. Similarly, electricity consumption has a mean value of 1.17E+10 and a standard deviation of 5.85E+09, indicating differences in electricity usage across the entities. CO2 emissions from electricity consumption (CO2_elect) and CO2 intensity (CO2_inten) provide insights into the environmental impact of energy usage. The mean CO2 emissions from electricity consumption are around 11.92061, with a standard deviation of 3.821687, indicating variations in emissions levels. CO2 intensity, representing CO2 emissions per unit of energy consumption, has a mean of 0.8527273 and a standard deviation of 0.2387896, highlighting differences in emissions efficiency across the entities. Oil consumption (Oil_cons) and gas consumption (Gas_cons) variables quantify the utilization of these energy sources. Oil consumption has a mean value of 3.26E+07, with a standard deviation of 6808935, while gas consumption has a mean of 5.24E+09 and a standard deviation of 2.62E+09. These statistics underscore the varying reliance on different energy sources among the observed entities. Overall, the descriptive statistics provide valuable insights into the economic, energy, and environmental profiles of the entities under consideration, highlighting the diversity and variability across these dimensions.

Table 1: Descriptive statistics.

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

The table 2 presents the results of the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests for various variables. These tests are conducted at both the level and first difference to assess stationarity. For the Gross Domestic Product (GDP) variable, both ADF and PP tests indicate stationarity at the first difference level, with highly significant p-values (0.0000), suggesting that GDP is integrated of order one, denoted as I(1). Similarly, energy consumption (En_cons), electricity consumption (Elect_cons), and carbon dioxide emissions from electricity consumption (CO2_elect) also exhibit stationarity at the first difference level, with significant p-values (0.0000). This implies that these variables are integrated of order one (I[1]). Oil consumption (Oil_cons) demonstrates stationarity both at the level and first difference, with highly significant p-values (0.0000). However, gas consumption (Gas_cons) is stationary only at the first difference, indicating integration of order one (I[1]). CO2 intensity (CO2_inten) exhibits stationarity at both levels and first differences, with significant p-values (0.0000). This suggests that CO2 intensity is integrated of order one (I[1]). Overall, the unit root tests provide insights into the stationarity properties of the variables, essential for subsequent time series analysis and modeling.

Table 2: ADF and PP unit root test

Variables	ADF Level	1st Difference	PP Level	1st Difference	Unit root
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]

The table 3 presents the results of the ZA unit root test for various variables, examining both the level and first difference to assess stationarity. Additionally, it identifies break dates and the order of integration. For the Gross Domestic Product (GDP) variable, the ZA test statistic is -3.748 at the level, indicating stationarity. However, after differencing, the test statistic significantly decreases to -7.178, providing evidence of stationarity at the first difference level. The break date is identified as 1993, and the variable is integrated of order one (I[1]). Similarly, energy consumption (En_cons) demonstrates stationarity at both the level and first difference. The ZA test statistic is -3.927 at the level and significantly decreases to -6.006 after differencing. The break date is identified as 2001, and the variable is integrated of order one (I[1]). Electricity consumption (Elect_cons) exhibits stationarity only at the level, with a ZA test statistic of -4.666. After differencing, the test statistic slightly decreases to -4.763, but the variable remains non-stationary. The break date is identified as 1996, and the variable is integrated of order zero (I[0]). Oil consumption (Oil_cons) and gas consumption (Gas_cons) both demonstrate stationarity at the level, with ZA test statistics of -13.385 and -5.155, respectively. After differencing, the test statistics decrease significantly, indicating stationarity at the first difference level. The break dates are identified as 2007 for oil consumption and 2006 for gas consumption. Both variables are integrated of order zero (I[0]). Carbon dioxide emissions from electricity consumption (CO2_elect) and CO2 intensity (CO2_inten) exhibit similar patterns. They demonstrate stationarity at the level, with ZA test statistics of -4.918 and -4.694, respectively. After differencing, the test statistics decrease significantly, indicating stationarity at the first difference level. The break dates are identified as 2000 for CO2_elect and 2004 for CO2_inten. Both variables are integrated of order one (I[1]). These results provide insights into the stationarity properties of the variables, which are essential for time series analysis and modeling.

Table 3: ZA unit root test

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]

The table 4 presents the results of the Johansen cointegration test for various pairs of variables, assessing the number of cointegration relationships based on eigenvalues and trace statistics. For the pair of Gross Domestic Product (GDP) and energy consumption (En_cons), the test results indicate that there is no cointegration relationship when considering the null hypothesis of none, as the trace test statistic of 19.3037 exceeds both the 5% and 1% critical values. However, when considering the null hypothesis of at most one cointegration relationship, the trace test statistic of 0.1276 falls below the critical values, leading to an acceptance of the hypothesis. Similarly, for the pairs of GDP and electricity consumption (Elect_cons), GDP and gas consumption (Gas_cons), and GDP and carbon dioxide emissions from electricity consumption

(CO2_elect), the test results reject the null hypothesis of none cointegration, as the trace test statistics exceed the critical values. However, when considering the null hypothesis of at most one cointegration relationship, the trace test statistics fall below the critical values, indicating acceptance of the hypothesis. For the pair of GDP and CO2 intensity (CO2_inten), the results are mixed. The test results accept the null hypothesis of none cointegration based on the trace test statistic, as it falls below the critical values. However, when considering the null hypothesis of at most one cointegration relationship, the trace test statistic exceeds the critical values, leading to rejection of the hypothesis. These results provide insights into the potential long-term relationships between the pairs of variables under consideration, which is essential for understanding their interdependencies and conducting further analysis.

Table 4: Johansen cointegration test

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

The table 5 presents the results of a Vector Autoregressive (VAR) model with the dependent variable being the change in Gross Domestic Product (dGDP) and several explanatory variables, including the change in CO2 intensity (dCO2_inten). For the relationship between dGDP and itself, the coefficient estimate is 0.08 with a p-value of 0.937, indicating no significant relationship. When considering the relationship between dCO2_inten and dGDP, the coefficient estimate is -3.46 with a p-value of 0.001, denoted by **, indicating a statistically significant negative relationship. The 95% confidence interval for this coefficient ranges from -1.082984 to 2.997222. Regarding the relationship between dCO2_inten and itself, the coefficient estimate is 2.07 with a p-value of 0.038, indicating a statistically significant positive relationship. The 95% confidence interval for this coefficient ranges from 0.0146692 to 0.5344823. Finally, for the relationship between dCO2_inten and the constant term, the coefficient estimate is 0.19 with a p-value of 0.847, indicating no significant relationship. The 95% confidence interval for this coefficient ranges from -0.2934746 to 0.3577862. These results provide insights into the dynamic interactions between changes in GDP and CO2 intensity, indicating significant relationships between some variables while others show no significant associations.

Table 5: Vector Autoregressive

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

Table 6: GH test result for GDP-En

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

The table 6 presents the results of the GH test for the relationship between GDP and Energy Consumption (En_cons). Three different models are considered: constant (C), constant with trend (C/T), and constant with structural break (C/S).

For the C model, the Za* statistic is -12.37, indicating a significant break in 2004. The Zt* statistic is -3.20, also pointing to a break in 2004. Additionally, the ADF* statistic is -2.89, suggesting a break in 1989.

In the C/T model, the Za* statistic is -15.95, indicating a significant break in 2002. The Zt* statistic is -3.16, pointing to a break in 2002 as well. The ADF* statistic is -3.11, suggesting a break in 2002.

Lastly, in the C/S model, the Za* statistic is -14.34, indicating a significant break in 1996. The Zt* statistic is -3.14, also pointing to a break in 1996. The ADF* statistic is -3.04, suggesting a break in 2000.

These results provide insights into the structural breaks in the relationship between GDP and Energy Consumption, indicating significant shifts in the relationship at different points in time under different model specifications.

The GH test results presented in Table 7 shed light on the dynamics of the relationship between Energy Consumption (En_cons) and GDP across different model specifications. These models aim to capture variations in the relationship over time, considering factors like trend and structural breaks. In the first model (C), which includes only a constant term, the analysis indicates a significant structural break in 1988. Both the Za* and Zt* statistics suggest this break, with values of -14.05 and -3.56, respectively. Furthermore, the ADF* statistic of -3.39 further supports the presence of a break, albeit in 1989. Moving to the C/T model, which incorporates a constant with a trend, the results point to a significant break occurring in 2000. The Za* and Zt* statistics show values of -23.98 and -4.41, respectively, indicating this structural shift. Additionally, the ADF* statistic of -4.20 aligns with this finding, suggesting a break in 2007. Lastly, in the C/S model, where a constant with a structural break is considered, the analysis reveals a significant break in 1990. The Za* statistic of -21.52 and the Zt* statistic of -3.93 both support this conclusion. Similarly, the ADF* statistic, also at -3.93, reinforces the presence of a break in 1990. These results emphasize the importance of accounting for structural breaks and trends when analyzing the relationship between Energy Consumption and GDP. Understanding these dynamics is crucial for policymakers and researchers in formulating effective energy and economic policies.

Table 7: GH test result for En_cons-GDP

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

Table 8 presents the results of the GH test for the relationship between GDP and CO2 intensity (GDP-CO2_inten) under different model specifications. These models aim to capture changes in the relationship over time, considering factors like trend and structural breaks. In the first model (C), which includes only a constant term, the analysis indicates a significant structural break in 2005. Both the Za* and Zt* statistics suggest this break, with values of -15.25 and -3.24, respectively. Additionally, the ADF* statistic of -3.04 further supports the presence of a break in 2006. Moving to the C/T model, which incorporates a constant with a trend, the results point to a significant break occurring in 2007. The Za* and Zt* statistics show values of -16.26 and -3.63, respectively, indicating this structural shift. Interestingly, the ADF* statistic of -4.72 suggests a break in 2006, which contrasts with the Zt* result. Lastly, in the C/S model, where a constant with a structural break is considered, the analysis reveals a significant break in 2006. The Za* statistic of -15.28 and the Zt* statistic of -3.21 both support this conclusion. Similarly, the ADF* statistic, also at -3.09, reinforces the presence of a break in 2006. These findings underscore the importance of accounting for structural breaks and trends when examining the relationship between GDP and CO2 intensity. Understanding these dynamics is crucial for informing environmental policies and sustainability efforts.

Table 8: GH test result for GDP-CO2

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

Table 9: GH test result for GDP-CO2

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

Table 9 presents the GH test results for the relationship between GDP and CO2 emissions from electricity production (GDP-CO2_elect) under different model specifications, aiming to capture variations in this relationship over time. In the first model (C), with only a constant term, the analysis indicates a significant structural break in 2002. Both the Za* and Zt* statistics support this, with values of -15.34 and -3.77, respectively. The ADF* statistic of -2.85 further corroborates a break in 2002. Transitioning to the C/T model, which incorporates a constant with a trend, the results also show a significant break in 2002. The Za* statistic of -20.71 and the Zt* statistic of -3.57 both support this structural shift. Additionally, the ADF* statistic of -3.51 aligns with these findings, indicating a break in 2002. In contrast, the C/S model, which includes a constant with a structural break, yields different results. It indicates a break in 1992, as evidenced by the Za* statistic of 15.61 and the Zt* statistic of -3.08. The ADF* statistic of -3.03 further supports this, suggesting a structural shift in 1992. These findings underscore the importance of considering different model specifications when assessing the relationship between GDP and

CO2 emissions from electricity production. Understanding the timing and nature of these structural breaks is crucial for informing environmental policies and promoting sustainable development initiatives.

Table 10 displays the outcomes of Granger causality tests for various pairs of variables, examining whether one variable Granger causes another. The null hypothesis for each test is that the first variable does not Granger cause the second variable. For the pair GDP and En_cons, the t-statistic (x^2) is 0.093753 with a corresponding probability (Prob>t) of 0.0014. This result suggests rejecting the null hypothesis that GDP does not Granger cause En_cons, indicating that there is evidence of Granger causality from GDP to En_cons. Conversely, for the pair En_cons and GDP, the t-statistic is 0.091883, and the probability is 0.6599, indicating insufficient evidence to reject the null hypothesis. Thus, En_cons does not Granger cause GDP. Similarly, for the pairs GDP and Elect_cons, GDP and Gas_cons, and GDP and CO2_elect, the tests yield t-statistics of 0.019282, 0.108856, and 0.106097, respectively. In all these cases, the probabilities are below conventional significance levels, suggesting rejecting the null hypothesis for GDP causing these variables. Conversely, for the pairs Elect_cons and GDP, Gas_cons and GDP, and CO2_elect and GDP, the tests result in t-statistics of -0.230044, -0.349090, and -0.000478, respectively. The probabilities associated with these statistics are above conventional significance levels, indicating insufficient evidence to reject the null hypothesis for causality from these variables to GDP.

Table 10: Causality Outcomes

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

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 the Gregory and Hansen (GH) test contradicts the studies carried out by Ebohon (1996), Wolde-Rufael (2006), Omisakin (2008), Omotor (2008), Gbadebo and Okonkwo (2009), Emeka (2010), Orhewere and Henry (2011), Dantama, Abdullahi, and Inuwa (2012), Akpan and Akpan (2012), Abalaba and Dada (2013), Kabir, Zaku, and Tukur (2013), Njindan (2014), as well as Nwosa (2013) and 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 in the long run. This implies that the government should focus on improving power generation in the country to meet the growing demand, which will also increase Nigeria's economic growth in the short run. This finding aligns with the studies carried out by Wolde-Rufael (2006) and Emeka (2010) but contradicts the findings of Okoligwe and Ihugba (2014) .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 CO_2 emissions from electricity generation in the short and long-run, but a change in CO_2 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 CO_2 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 CO_2 intensity showed a unidirectional relationship with causality running from economic growth to CO_2 emission intensity. Since CO_2 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 CO_2 emission should be explored by the Nigerian government to address CO_2 emission challenges without sacrificing the country's economic growth.

5. CONCLUSION

Nigeria, a signatory to the Kyoto Protocol, faces the dual challenge of curbing CO_2 emissions while sustaining economic growth. Achieving this balance necessitates efficient fossil fuel utilization or transitioning to renewable energy sources. However, the impact of these strategies on economic growth remains uncertain. To address this, we reexamined the nexus between CO_2 emissions, energy consumption, and economic growth in Nigeria from 1980 to 2020. Given Nigeria's status as an energy-led-growth economy, susceptible to global oil price fluctuations, structural breaks in economic data are likely. Given the conflicting findings of prior research that overlooked structural breaks, our study employs two sets of analyses in both unit root and cointegration tests. In the unit root test, we utilized both the standard Augmented Dickey-Fuller and Phillips-Perron tests, which do not incorporate structural breaks, alongside the Zivot and Andrews test. Similarly, in the cointegration analysis, we employed two approaches: the Johansen cointegration test, which disregards structural breaks, and the Gregory and Hansen test, which considers them.

Our findings revealed cointegration between economic growth and various factors including energy consumption, electricity consumption, gas consumption, and CO_2 emissions from power generation. However, when accounting for structural breaks, only economic growth and CO_2 emission intensity exhibited cointegration. Notably, the identified structural break in 2006 was consistent across all three models. The identified breakpoint in 2006 coincided with significant energy sector reforms and a sharp uptick in fuel subsidies attributed to rising oil prices and a depreciating exchange rate. This finding diverged from our Johansen test outcome and contradicted prior studies that overlooked structural breaks. Finally, we explored the short-run and long-run causal relationships among our variables based on the cointegration results. Employing the Granger causality test, we observed bidirectional causality in both the short run and long run between economic growth and energy consumption, as well as between economic growth and gas consumption. The study revealed a unidirectional causal link from electricity consumption to economic growth, and from economic growth to CO_2 emission intensity.

In the long run, only economic growth and gas consumption exhibited a bidirectional causal relationship. Unidirectional causality was also observed from economic growth to energy consumption, electricity consumption, and CO_2 emissions from power generation. Based on these findings, policymakers should carefully consider the short-term impact of energy conservation policies on Nigeria's economic growth. Instead, the focus should be on implementing energy efficiency measures that do not impede economic growth, alongside effective energy policy formulation. However, in the long run, energy conservation policies can be pursued without concern for their impact on economic growth, given the established causality from economic growth to energy consumption over time. To enhance gas consumption in Nigeria, efforts should be made to intensify gas development both in the short and long term. This can be achieved through the introduction and improvement of natural gas utilization across various sectors of the economy, including households, transportation, agriculture, and manufacturing.

Electricity rationing or conservation may not be advisable for Nigeria, as it could negatively impact economic growth in the short run. This is supported by our findings, which indicate a causal relationship from electricity consumption to economic growth in the short term. Instead, Nigeria should focus on diversifying its energy sources to reduce CO_2 emissions from electricity generation and energy combustion, as evidenced by the causality running from economic growth to CO_2 emissions. Fortunately, Nigeria boasts abundant renewable energy resources such as solar, wind, hydropower, and biomass. Leveraging these resources could enhance the country's energy security, promote sustainability, and mitigate greenhouse gas emissions from fossil fuel use. Future research endeavors should concentrate on examining the effects of structural breaks in the relationship between energy consumption and economic growth, particularly in oil and gas exporting nations like those in OPEC. These countries heavily rely on oil export revenues, making their economies susceptible to fluctuations in oil prices, which can lead to structural breaks in economic data. Therefore, conducting time series analyses that account for these structural shifts is crucial. By doing so, policymakers can derive more accurate insights and formulate effective energy policies that support both economic development and environmental conservation.

REFERENCES

Abalaba, B. P., & Dada, M. A. (2013). Energy consumption and economic growth nexus: new empirical evidence from Nigeria. *International Journal of Energy Economics and Policy*, 3(4), 412-423.

Abrokwah-Koranteng, M. (2013). The relationship between energy consumption and economic growth in Ghana. (Unpublished master's thesis). Seoul National University, Seoul, Republic of Korea.

Akpan, G. E., &Akpan, U. F. (2012). Electricity consumption, carbon emissions and economic growth in Nigeria. *International Journal of Energy Economics and Policy*, 2(4), 292-306.

Banafea, W. A. (2014). Structural Breaks and Causality Relationship between Economic Growth and Energy Consumption in Saudi Arabia. *International Journal of Energy Economics and Policy*, 4(4), 726-734.

Bilen, K., Ozyurt, O., Bakırcı, K., Karslı, S., Erdogan, S., Yılmaz, M., & Comaklı, O. (2008). Energy production, consumption, and environmental pollution for sustainable development: A case study in Turkey. *Renewable and Sustainable Energy Reviews*, 12(6), 1529-1561.

Clements, R., & Practical, A. C. (2009). The economic cost of climate change in Africa. *Pan African Climate Justice Alliance (PACJA)*.

Dantama, Y. U., Abdullahi, Y. Z., &Inuwa, N. (2012). Energy consumption-economic growth nexus in Nigeria: an empirical assessment based on ARDL bound test approach. *European Scientific Journal*, 8(12).

Demirbaş, A. (2003). Energy and environmental issues relating to greenhouse gas emissions in Turkey. *Energy Conversion and Management*, 44(1), 203-213

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American statistical association*, 74(366a), 427-431.

Dickey, D. A., & Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. Econometrica: *Journal of the Econometric Society*, 1057-1072.

Ebohon, O. J. (1996). Energy, economic growth and causality in developing countries: a case study of Tanzania and Nigeria. *Energy Policy*, 24(5), 447-453.

Emeka, E. E. (2010). Causality Analysis of Nigerian Electricity Consumption And Economic Growth. *Journal of Economics & Engineering*, (4).

Gbadebo, O. O., & Okonkwo, C. (2009). Does energy consumption contribute to economic performance? Empirical evidence from Nigeria. *Journal of Economics and Business*, 12(2).

Gregory, A. W., & Hansen, B. E. (1996). Residual-based tests for cointegration in models with regime shifts. *Journal of econometrics*, 70(1), 99-126.

Gregory, A. W., Nason, J. M., & Watt, D. G. (1996). Testing for structural breaks in cointegrated relationships. *Journal of Econometrics*, 71(1), 321-341.

Halicioglu, F. (2009). An econometric study of CO 2 emissions, energy consumption, income and foreign trade in Turkey. *Energy Policy*, 37(3), 1156-1164.

International Energy Agency (IEA) Online Statistics Report.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of economic dynamics and control*, 12(2), 231-254.

Kabir, A., Zaku, S. G., &Tukur, A. A. (2013). The relationship between energy consumption and national income of Nigeria. *Journal of Economics and International Finance*, 5(2), 53-57.

Njindan, I, B. (2014). Electricity Consumption, Inflation, and Economic Growth in Nigeria: A Dynamic Causality Test (No. 57818). University Library of Munich, Germany.

Nwosa, P. I. (2013). Long run and short run effects between domestic fuel consumption and economic growth in Nigeria. *Journal of Sustainable Development in Africa*, 15(4), 130-142.

Okoligwe, N. E., &Ihugba, O. A. (2014). Relationship between Electricity Consumption and Economic Growth: Evidence From Nigeria (1971-2012). *Academic Journal of Interdisciplinary Studies*, 3(5), 137.

Omisakin, O. A. (2008). Energy consumption and economic growth in Nigeria: A bounds testing cointegration approach. *Journal of Economic Theory*, 2(4), 118-123.

Omotor, D. G. (2008). Causality between Energy Consumption and Economic growth in Nigeria. *Pakistan Journal of Social Sciences*, 5(8), 827-835.

Orhewere, B., & Henry, M. (2011). Energy Consumption and Economic Growth in Nigeria. *Journal of Research in National Development*, 9(1).

Osundina, O., Kemisola, C., and Odukale, D. (2014). Causality effect of energy consumption and economic growth in Nigeria (1980-2012). *International Journal of Recent Research in Commerce Economics and Management*, 1(3), 1-9.

Perron, P. (1989). The great crash, the oil price shock, and the unit root hypothesis. *Econometrica: Journal of the Econometric Society*, 1361-1401.

Phillips, P. C., &Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, 75(2), 335-346.

Said, S. E., & Dickey, D. A. (1984). Testing for unit roots in autoregressive-moving average models of unknown order. *Biometrika*, 71(3), 599-607.

Sen, A. (2003). On unit-root tests when the alternative is a trend-break stationary process. *Journal of Business & Economic Statistics*, 21(1), 174-184.

Wolde-Rufael, Y. (2006). Electricity consumption and economic growth: a time series experience for 17 African countries. *Energy Policy*, 34(10), 1106-1114.

Zivot, E., & Andrews, D. W. K. (2002). Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. *Journal of Business & Economic Statistics*, 20(1), 25-44.