



NEXUS BETWEEN CARBON DIOXIDE EMISSION, ENERGY CONSUMPTION AND ECONOMIC GROWTH IN NIGERIA

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ABSTRACT

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Granger causality.

This study investigated the nexus between carbon dioxide emission, energy consumption and economic growth in Nigeria covering the year 1980-2016. The study use secondary source of data that were sourced from various energy parastatal database, these data were analyzed using the Granger block exogeneity (wald test) and the Vector Autoregressive (VAR) with more emphasis on the impulse response and variance decomposition. GDP was found to be associated with increase in carbon emission in the Nigerian case, while primary energy consumption and emissions are positively related. This positive relationship, conforms to theoretical expectation, because of the large surplus in the supply and less than proportionate surplus demand of primary energy consumption in Nigeria. It was also found that the shock to all our variables are not necessarily available always i.e long run. Following the findings of the study; it recommended that investment in energy sector which facilitate diversification reduce carbon dioxide emission and meet up with raising energy demand should be in place. Also recommends that the need to use more energy conservation methods to increase the efficient use of energy and thus promote economic growth and improve environmental quality in Nigeria.

Contribution/Originality: This study contributes to existing literature by investigating the nexus between carbon dioxide emission, energy consumption and economic growth in Nigeria covering the year 1980-2016.

1. INTRODUCTION

It is the aim of every developed and developing economy of the world to attain a certain level of economic growth and sustainable development. According to Iwayemi (2008) energy is a capacity or matter to perform work as a result of its motion or position in relation to forces on it. Today, energy has been the heart of most critical economic, environmental and developmental issues in the global world which has contributed significantly to climate degradation through carbon emission-(a gas in the atmosphere causing radiation within the environment), this is why Kulionis (2013) termed energy as the lifeblood of any modern economy because of its essential input to nearly all of the production we have today. The rapid surge in economic activities around the world has caused a significant increase in carbon dioxide (CO₂) emission. As heavy use of energy and other natural resources cause environmental deterioration, also the gas emissions from energy consumption increases the amount of CO₂ which harms the environment as well as inflicting irreparable damages on the atmosphere.

Therefore, the complex nature of the relationship between pollutant emissions, energy consumption and economic growth process has been a subject of inquiry among scholars and policy analysts since energy is

considered as an important driving force of economic growth. An understanding of this tripartite relationship in Nigeria becomes important in charting a pathway towards ensuring sustainable development.

The actual contributions of energy consumption towards economic growth and emission of CO₂ can be questioned in Nigeria. Certain energy source like hydropower, fossil fuel and biomass are reliable and easily predictable in the production process of the industrial sector of economy, and thus there is no doubts about their contribution towards economic growth. However, problem rises where the more energy produced lead to higher carbon dioxide emission. Although Nigeria's GDP is increasing but due to high amount of energy produced, the amount of carbon dioxide release could cause greenhouse effect, [Aliero and Ibrahim \(2012\)](#).

Given the importance of the above mentioned issue and challenges associated with them, it is not surprising that the relationship between the economic growth, carbon dioxide emission and energy consumption has been amongst the most debated topics over the past few decades in energy economics. There is however a minimal amount of empirical studies that investigates both relationships of linkage between economic growth and energy consumption and between economic growth and environmental pollution caused by carbon dioxide emission in one framework. Particularly, there is a significant lack of research that looks at primary energy consumption instead of aggregate energy consumption using modern econometric techniques associated with causality testing. Thus, the need for a study that inculcate primary energy consumption, carbon dioxide emission and economic growth for perfect understanding of the variables.

The overall aim of this study is to find out the effect of Carbon dioxide emission and energy consumption on economic growth in Nigeria. While, the specific objectives include: examining the dynamic interactions among carbon dioxide emission (CO₂), energy consumption and economic growth in Nigeria; understanding if there is short run or long run relationship between CO₂ emission, energy consumption and economic growth in Nigeria ; and to investigate the nature and direction of the relationship between CO₂emission, energy consumption and economic growth.

The rest of the paper is organized as follows: section two reviews some the existing literature, section three deals with the methodology employed in the study, section four presents empirical results and discussion of findings and finally, section five concludes the paper and offers some policy implications and recommendations.

2. LITERATURE REVIEW

2.1. Theoretical Framework

This study adopts the Environmental Kuznet Curve hypothesis because the relationship between output and pollution level has also been well discussed in the literature of Environmental Kuznets Curve (EKC) where environmental degradation initially increases with the level of per capita income then it reaches a turning point and declines with further increases in per capita income ([Grossman & Krueger, 1991](#); [Shafik & Bandyopadhyay, 1992](#)). [Martí nez-Zarzoso and Bengochea-Morancho \(2004\)](#) found evidence that CO₂ emissions and national income are negatively related at low income levels, but positively related at high-income levels just as in the case of Nigeria. However, increased national income level does not necessarily warrant greater efforts to contain the emissions of pollutants. The empirical results of [Shafik \(1994\)](#) and [Douglas and Selden \(1995\)](#) show that pollutant emissions are monotonically increasing with income levels.

2.2. Empirical Literature Review

A swift view of the literature shows that a number of studies that have examined the CO₂ emissions, energy-economic growth nexus using different methodology and arriving at various results Some of the studies used ARDL, like the studies of [Cosimo \(2016\)](#); [Chebbi and Boujelbene \(2008\)](#) and [Spetan \(2016\)](#). The study of [Monika \(2013\)](#); [Obradović and Lojanica \(2017\)](#); [Adedokun and Tajudeen \(2016\)](#); [Endeg, Wendaferahu, and Muhdin \(2016\)](#); [Khalid, Muhammad, and Muhammad \(2012\)](#); [Negin \(2018\)](#) used VECM in their analysis. Very few studies used

VAR and Granger causality test as their method of analysis; studies like [Linh and Khanh \(2017\)](#); [Dinh and Lin \(2015\)](#) and [Tiwari \(2011\)](#).

Based on the findings of some of the related studies; studies of [Chebbi and Boujelbene \(2008\)](#) found a long run relationship between the variables under study but rejected the EKC while [Mehmet and Manga \(2016\)](#); [Dinh and Lin \(2015\)](#) support the hypothesis of EKC. Some studies also found no causality between carbon dioxide emissions to energy consumption and from economic growth studies like [Monika \(2013\)](#); [Obradović and Lojanica \(2017\)](#) but [Cosimo \(2016\)](#) rejected the neutrality assumption and found unidirectional relationship between energy consumption and economic growth; Studies of [Khalid et al. \(2012\)](#); [Adedokun and Tajudeen \(2016\)](#); [Spetan \(2016\)](#); [Linh and Khanh \(2017\)](#); [Negin \(2018\)](#) found bidirectional long run relationship between energy consumption and economic growth while [Endeg et al. \(2016\)](#) exert an insignificant relationship between energy consumption and CO₂ emission but a significant and positive relationship between economic growth and CO₂. These contradictory results mentioned above have been ascribed to the different data set and time period, alternative econometric methodologies and different countries' peculiarities among other things [Acaravci and Ozturk \(2010\)](#).

There are but a few literatures on the study which are of other Africa countries. This research will serve as a means to include more to the country specific research using Nigeria as the case study. The methodology of related studies are also gap identified as most of them are panel data but the few univariate studies make use of OLS, VECM and ARDL. This study will be using the VAR to test the hypothesis of the study and other related techniques.

3. METHODOLOGY

3.1. Data Source and Variables Description

This research study will use annual time series data for the years 1980-2016 in empirical investigation of this study, the data to be used for this research work will be generated mainly from secondary sources. This period was selected because it serve as the era for innovation and constant use of energy in production process through industrialization. Also, this sample period is chosen based on the overall aim of this study-the effect of Carbon dioxide emission and energy consumption on economic growth in Nigeria.

The variables in this study are; Carbon dioxide emission in metric tons per capita (CO₂) to serve as the dependent variable. While Primary Energy Consumption in kg of oil equivalent per capita (PEC), and Real Gross Domestic Product (GDP) were used as the independent variables. The CO₂ and PEC data taken from the International Energy Agency (IEA), and GDP per capita in constant 2010 US\$ (GDP) data taken from the World Bank Development Indicators (World Development Indicators (WDI), 2017).

A problem of sourcing data beyond the stated time was encountered because the source of the data for GDP only release the compiled data every 2years which was not available as at the time of compilation of this work; thus the restriction of this study scope to 2016.

3.2. Model Specification

To estimate the magnitude and overall effect of carbon dioxide emission and energy consumption on economic growth in Nigeria. The model employed in this this research work is based on the modification of the models employed in [Papież \(2013\)](#) and [Lean and Smyth \(2009\)](#) chose the following variables which are: CO₂= f (energy consumption, GDP, GDP²);

[Akpan and Akpan \(2012\)](#) whose model is specified as $Y=f(CO_2, PEC, L)$; and also based on the variables implied by environmental kuznet curve framework adopted.

This study specifies a carbon dioxide emission equation using carbon dioxide emission (CO₂) as a proxy for carbon dioxide emission and two explanatory variables including, Primary Energy consumption (PEC) and Gross Domestic Product 2010 USD Constant (GDP). Square of Gross Domestic Product 2010 USD Constant (GDP²) is included in the model to inculcate the theoretical backing for environmental kuznet curve. Therefore, the following

functional form of carbon dioxide emission equation is specified. Therefore, time series data has a tendency of having the problem of heteroscedasticity and abnormal distribution because of outliers. To secure normality and homoscedasticity of these variables, the study takes natural log of these variables giving us a double log linear model. Algebraically, the relationship can be expressed in Equation 1:

$$\ln CO_2 = \beta_0 + \beta_1 \ln PEC + \beta_2 \ln GDP + \beta_3 \ln GDP^2 + \mu \quad (1)$$

Where;

$\ln CO_2$ = the logarithm of Carbon dioxide Emission in (mm tons).

$\ln PEC$ = the logarithm of Primary Energy consumption (Quad Btu).

$\ln GDP$ = the logarithm of Gross Domestic Product (2010 USD Constant).

$\ln GDP^2$ = the logarithm of Square of Gross Domestic Product (2010 USD Constant).

β_1, β_2 and β_3 = the coefficients of explanatory variables.

β_0 is the slope intercept while β_1, β_2 and β_3 are the coefficients of explanatory variables in the above model. The theoretical (a priori) expectation of the model is that: β_1 and β_2 should be greater than zero (i.e. positive) while

β_3 should be less than zero (i.e. negative). Where μ take into account the influence of omitted variables as well as any error of measurements. The μ is the random term and it is assumed to be normally and identically distributed around zero mean and constant variance ($\mu \sim N(0, 1)$).

The VAR model provides a multivariate framework where changes in a particular variable (carbon dioxide) are related to changes in its own lags and to changes in other variables (primary energy consumption and economic growth) and the lags of them. The VAR treats all variables as endogenous and does not impose a priori restrictions on structural relationships. Since the VAR expresses the dependent variables in terms of predetermined lagged variables in a certain periods, it is a reduced-form model.

The general VAR model specification in an economy is assumed to be structured in Equation 2 as follows:

$$Y_t = C + A(L)Y_{t-1} + B(L)X_t + \varepsilon_t \quad (2)$$

In Equation 2 above, Y_t is a vector of endogenous variables, X_t is a vector of the exogenous variables, and C is a vector of residuals. In addition, A & B are the matrices of the estimated coefficients describing the relationships among the endogenous variables and exogenous variables, respectively. While L is as a lag operator of length p ; and ε_t is a vector of the error terms which are I.I.D (0, 1). However, the vector of the exogenous variables can be excluded to obtain the reduced form of VAR model as follows:

$$Y_t = C + A(L)Y_{t-1} + \varepsilon_t \quad (3)$$

In Equation 3 above, the error term (ε_t) now is a vector of random components of error terms for all the variables in the model and it captures the influence of the excluded exogenous factors and A is a matrix containing the contemporaneous response of the variables to the innovations.

4. EMPIRICAL RESULTS & DISCUSSION

4.1. Unit Root Test Results

The unit root tests results, based on ADF and PP tests are presented below in Table 1. From the two tests, it is clear that all the variables are not stationary at levels but found to be stationary at first difference. This is because, at levels, the observed values of the statistics are not greater than their respective critical values in both intercept

and linear trend. While at the first difference, the null hypotheses of all the variables are rejected, given that the observed values of the statistics are not less than their corresponding critical values, all at 1% significance level. Evidently, both the two tests reveal the same outcomes- implying that all the variables are integrated of the same order one [i.e. I (1)]. Thus, a long run relationship may exist among the variables and consequently the next step is to test if such long relationship actually exists or not among the variables.

Table-1. Augmented dickey fuller (ADF) and Phillips-Perron (PP) unit root test results.

Variable	ADF				PP				Order of Integration
	Level		First Difference		Level		First Difference		
	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	
lnCO2	-1.350	-2.152	-6.075*	-5.995*	-1.371	-2.269	-6.075*	-6.006*	I (1)
lnPEC	-1.032	-3.167	-7.619*	-7.525*	-0.771	-3.271	-7.700*	-7.613*	I (1)
lnGDP	-0.166	-3.075	-4.851*	-5.057*	-0.524	-3.012	-4.847*	-5.062*	I (1)
lnGDP2	-0.128	-3.087	-4.861*	-5.069*	-0.493	-3.087	-4.858*	-5.074*	I (1)

It is important to know the optimal lag length before the co-integration test is conducted because the Johansen Multivariate Co-integration test can be misleading if not carried out using the right lag length. Likewise, the estimation of the VAR model associated with the co-integrating vector if any exist, is very sensitive to the initial selected optimal lag length. The optimal number of lag length needed in our forthcoming Johansen Multivariate Co-integration test and the subsequent VAR model estimations will be based on one lag length (i.e. setting p=1) based on the lowest value of the test statistics (i.e the lower the value of the test statistics the better the model fit the data) and vice versa. The optimal lag length suggested by AIC and FPE will be used even though they are better choice under smaller sample, they are found to produce the least probability of under estimation among all criteria under study (Liew, 2004). Thus, 1 optimal lag lengths were used in the VAR model estimations.

4.2. Cointegration Test Results

The estimated results of the Johansen Multivariate cointegration test for both Trace criterion and the Maximum Eigenvalue criterion are presented below on the Table 2a and Table 2b, respectively

Table-2a. Johansen multivariate co-integration test (Trace).

Hypotheses		Eigenvalue	(λ_{trace}) Statistic	0.05 Critical Value	Prob.**
H0	H1				
r=0	r>0	0.428329	38.54111	47.85613	0.2789
r≤1	r>1	0.268462	18.96942	29.79707	0.4951
r≤2	r>2	0.195481	8.028188	15.49471	0.4624
r≤3	r>3	0.011796	0.415321	3.841466	0.5193

4.3. Trace Test Indicates No Co-Integration at 5% Significant Level

Table-2b. Johansen multivariate co-integration test (Maximum Eigenvalue).

Hypotheses		Eigenvalue	(λ_{trace}) Statistic	0.05 Critical Value	Prob.**
H0	H1				
r=0	r>0	0.428329	19.57169	27.58434	0.3715
r≤1	r>1	0.268462	10.94123	21.13162	0.6532
r≤2	r>2	0.195481	7.612867	14.26460	0.4194
r≤3	r>3	0.011796	0.415321	3.841466	0.5193

4.4. Max-Eigenvalue Test Indicates no Cointegration at 5% Significant Level

From the two tables above, it can be observed that neither the Trace test nor the eigenvalue test rejected the first null hypothesis of no co-integration (i.e. r =0) at the 5% significant level, since the trace test's critical value is

greater than the trace statistics. This means that the tests indicates the existence of zero co-integrating vector at the 5% level of significance in both cases. Thus, we can conclude that, there is no long run relationship among the carbon dioxide emission, energy consumption and economic growth in Nigeria for the scope of this study.

4.5. VAR Granger Causality Test Results

The dynamic natures of the causal interactions among the variables of concern will be analyzed first before estimating the VAR models using a technique of Granger causality test. The Granger causality test allows for several causal relationships to be identified in different alternative models. Table 3 below shows the summary results of this causality test.

Table-3. VAR granger causality (block exogeneity) wald tests.

Inferences (Does not lead to)	lnCO2	lnPEC	lnGDP	lnGDP2
lnCO2 	=====	0.405057	0.947586	1.003970
lnPEC 	0.911168	=====	6.787761***	7.007279***
lnGDP 	0.819679	5.813656**	=====	1.597288
lnGDP2 	0.795594	5.904930**	1.516907	=====
JOINTLY 				
ALL 	4.077408	9.447208 **	13.40380***	13.62538***

Note that the Causality test is based on χ^2 statistic, with 1 degree of freedom, except for "All" which has 4 degrees of freedom; * ** & *** signifies statistical significant at 10%, 5% and 1%, respectively. And the symbol  means 'does not cause/lead to'.

From the Table 3 above, It can be seen that there is causal relationship between lnGDP, lnGDP2 and lnPEC at 5% level of significance. This means that the variable lnPEC causes or lead to lnGDP and lnGDP2 at 5%. In the same light lnGDP and lnGDP2 both cause lnPEC at 1% level of significance. To sum these all up the test revealed that there is a bidirectional relationship between lnPEC, lnGDP & lnGDP2; which conform to the feedback hypothesis, (Kulionis, 2013; Lim, Lim, & Yoo, 2014). It can also be seen that lnCO2 does not cause any of the variables in the model found to be perfectly exogenous as none of the variables in the model causes it and jointly all the variables do not cause it which conforms to the neutrality hypothesis.

In addition, all the variables in the model jointly leads to lnPEC, lnGDP and lnGDP2 at 5%, 1%, and 1% respectively. This adds up to mean primary energy consumption and economic growth in Nigeria is determined by them; when primary energy is consumed the economic growth will also add up. Therefore, this attests the endogeneity of these three variables and hence justifies the appropriateness of employing vector autoregressive (VAR) model in carrying out the empirical investigation of this research work.

4.6. Impulse Response Functions (IRFs)

Most of the previous studies stopped the interpretation and analysis with the granger causality test (Dinh & Lin, 2015; Sahbi & Rejeb, 2012; Wen-Cheng, 2017) among a few others), but this study attempt to move further by estimating the IRFs of the variables.

The impulse response function graphs help us gain more understanding about the interaction between the variables in the short-run. At large IRF analysis in time series analysis is important in determining the effects of external innovations on the variables of the system (that is how an unexpected change in one variable at the beginning affects another variable through time).

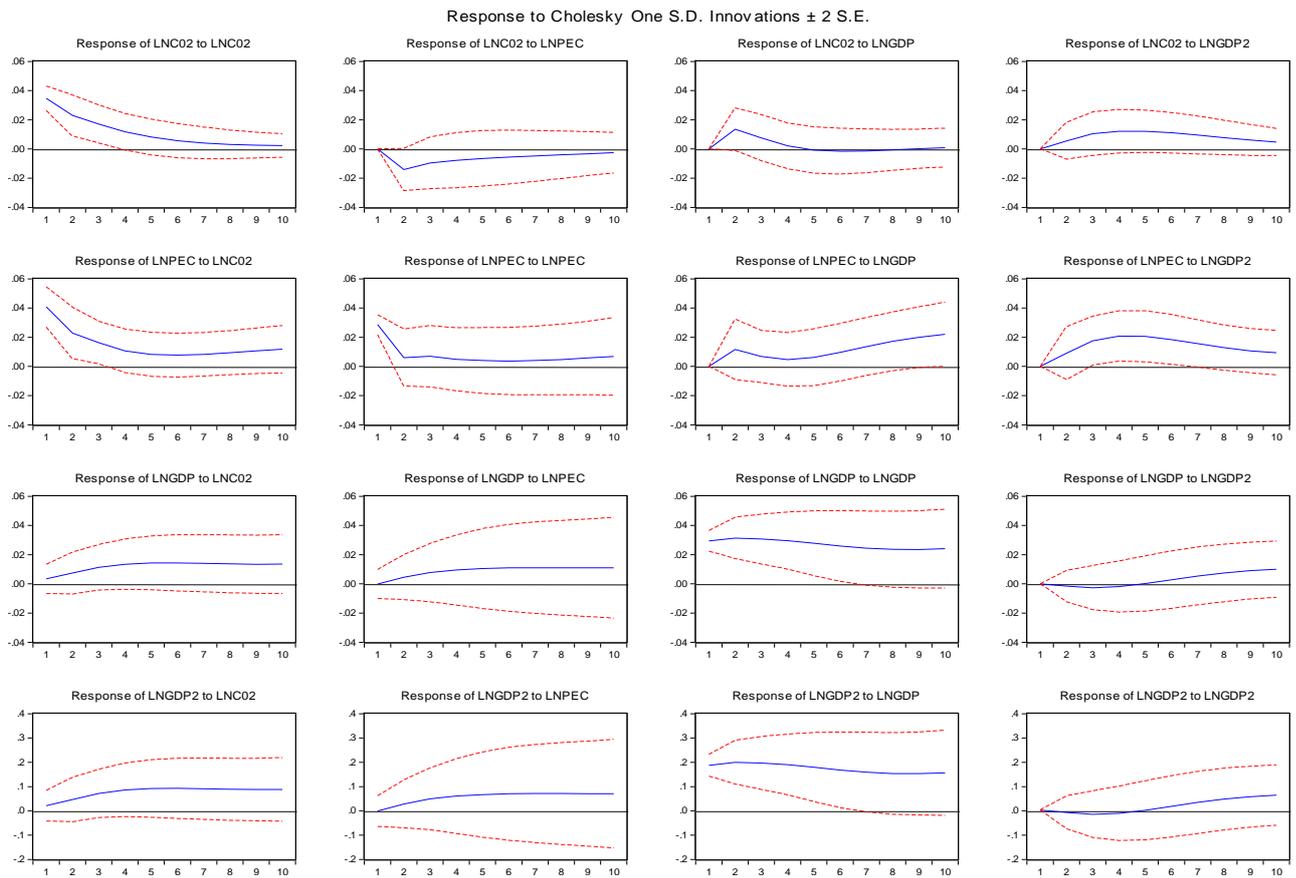


Figure-1. Impulse response and variance decomposition.

In the impulse response graphs, the solid (blue) lines show the responses of the endogenous variables to an innovation, while the dashed lines indicate the boundaries of 95% confidence intervals. If both the upper bound and the lower bound limit does not cross the zero line, then an innovation to an endogenous variable under consideration has no effect on the that particular variable (meaning the innovation is not statistically significant). Also, the effect of a one-time innovation is regarded as transitory shock if the variable shows a tendency to converge to zero; but if it does not, and then it is considered to be a permanent shock.

The Figure 1 above depicts the responses of the carbon dioxide emission (lnCO₂), primary energy consumption (lnPEC), and economic growth (lnGDP) to a positive standard deviation shock in all the variables. It conform to known knowledge because an increase in energy consumption and economic growth will also lead to an increase in carbon dioxide emission.

The graph one is the graph of carbon dioxide to itself, the innovation is statistically significant and it has a permanent shock to itself. The response is downward slopy with positive effect of itself. The graph two, depict the effect of carbon dioxide to primary energy consumption which has a negative impact or transitory through it, it increased across the years (4-10) following its fall from year (1-3). The graph three; depict the innovation of CO₂ to GDP are statistically significant with minimal means of convergence. The shock is temporary because it crossed and moved mostly on the zero line depicting an increasing and decreasing tendencies. The fourth graph; the shock to GDP2 is permanent with the response to it increasing after the constant from year 3-5 after which it started decreasing all through the 10 year.

The second set of graphs depict the innovations to primary energy consumption, the fifth graph depict the effect on carbon dioxide by primary energy consumption is significant and the shock is permanent. The impulse response started with a positive then a decreasing response and at a year 5-8. It is constant from the 9th year, it depict an increasing tendency. The sixth graph shows the relationship on PEC to PEC; the impulse on itself is a decreasing flow of the effect of it is significant with a constant and permanent innovation of it. The seventh graph

shows the relationship between PEC to GDP; the shock to it is permanent though insignificant. The response to it is an increasing then it fell from year 3-5 from which year 6 down to year 10 it increasing. The eighth graph shows the response to PEC to GDP²; shows a significant with permanent innovation. The response to the deviation are an increasing rate for few years before it became constant at 4-5 year. Then depict a decreasing rate response; this may be due to either over use of energy in unproductive sectors or inefficient energy supply. The third set of graphs shows the innovation from economic growth to all the other variable in the model. The innovation of GDP to CO₂ and PEC are permanent and insignificant. They also are increasing at the early years before becoming constant at the later years in graph nine and ten respectively. In graph eleven, the shock of GDP to itself is statistically significant and also exhibit a transitory permanent shock. The response is an increasing response for the earlier years before becoming constant. The twelfth graph is the analysis for the innovations of GDP to GDP² which are insignificant and permanent. Lastly the graphs of GDP² depicted as the last set of graphs indicated a permanent and insignificant shock though a positive response to CO₂ emission in the thirteenth graph . The fourteenth graph is the response of GDP² to PEC; having a permanent and insignificant innovations after depicting an increasing response in the early years after which it became constant for a few more years. The last graph of this study's IRF shows the response of GDP² on itself; this indicated an insignificant innovations. The shock is permanent and negative for the first for years before it increased down to the last years. In conclusion, the result of IRF conducted conforms to our chosen theory of EKC as the response of all our variables to the GDP² gave us an inverted U shape. Whereas a shock to GDP has a longer and positive impact on CO₂ emissions, implying that if there is a rapid growth in the economy, increased level of production will result in higher CO₂ emissions. The response of innovation of all other variables conforms to the known priori conditions or relations between them.

4.7. Post-Diagnostic Checks for the VAR Model

The big challenge in using VAR methodology is how robust are the results from estimated VAR model? In order to answer this question, the current study conducted three important diagnostic tests, namely, autocorrelation, heteroskedasticity and normality test. The Table 4 below presents the results of the diagnostic checks for the estimated VAR model.

Table-4. Summary of residual diagnostic checks for the VAR Model.

Residual Tests:	Statistics	P-value	Remark
Autocorrelation Test (LM stat.)	11.781	0.759	No Serial Correlation
Heteroskedasticity Test (Chi-Sq)	160.349	0.115	Residuals are Homoscedastic
Normality Test (J-B Stat.)	76.912	0.00	Not Normally Distributed

Table 4 above indicates that the estimated VAR model has no autocorrelation and heteroscedasticity problems. Nevertheless, there is a problem with and normality test that is our estimated VAR model is not normally distributed according to the J-B statistics. Though this is not a big problem according to Juselius (2006) because the residuals in the VAR do not need to be normally distributed if it is caused by the excess Kurtosis. Which is actually the case of the VAR model in this study; the VAR system has excess kurtosis, exceeding the value of 5-8 for the component 1& 3 i.e Carbon dioxide emission and economic growth. Therefore, based on the residual diagnostic tests results in the table above, the VAR systems estimated in this study performed very well, even though some fluctuations took place perhaps because of the abnormality problem.

5. CONCLUSION AND POLICY IMPLICATIONS

This paper tried to understand the relationship between CO₂ emissions, energy consumption on Nigeria's economic growth from 1980 to 2016 using the johansen multivariate cointegration, granger causality and impulse response. The empirical analysis in this study revealed no long run relationship between the variables under study. The EKC hypothesis was validated by our results. GDP was found to be associated with increase in carbon emission

in the Nigerian case, while primary energy consumption and emissions are positively related. This positive relationship, conforms to theoretical expectation, because of the large surplus in the supply and less than proportionate surplus demand of primary energy consumption in Nigeria. The result of IRF conducted conforms to our chosen theory of EKC as the response of all our variables to the GDP² gave us an inverted U shape. Whereas a shock to GDP has a longer and positive impact on CO₂ emissions, implying that if there is a rapid growth in the economy, increased level of production will result in higher CO₂ emissions. Thus, policies that are aimed at diversifying energy consumption through massive investment to energy sector to reduce carbon dioxide emission and meet up with the raising energy demand. Also Nigeria needs to use more energy conservation methods to increase the efficient use of energy and thus promote economic growth and improve environmental quality. Future research on the nexus between carbon dioxide emission, energy consumption and economic growth should include other types of energy consumption (such as electricity use rate, fossil fuel, oil price, and renewable energy consumption), which may help to better explain the impact of carbon dioxide emission, energy consumption and economic growth in Nigeria.

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