NATURAL GAS CONSUMPTION, ECONOMIC GROWTH AND CO2 EMISSION RELATIONSHIPS IN NIGERIA.

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ABSTRACT

The aim of this research is to estimate the relationship between natural gas consumption, economy growth and carbon (iv) oxide emission. This relationship was established for Nigeria using time series data inputs sourced from the International Bank for Reconstruction and Development (IBRD) between 1980 and 2016.

The usual preliminary analysis and formal tests were performed on the data, cointegration test was performed using Johansen's method and with the application of the Akaike information criterion (AIC), a lag value of one was selected. Based on no cointegration being observed which meant a short-run relationship, the Vector Autoregressive (VAR) model was applied in the model estimation. The VAR was also applied in the impulse response and variance decomposition anlaysis of the different variables to natural gas consumption shocks. The results of this investigation were then presented and diagnostic tests were also carried out on the estimated models.

The results coefficients for the multi-directional relationships between natural gas consumption, economic growth and carbon dioxide emission were obtained in the short run for Nigeria. A unidirectional Gragner Causality relationship was also determined between GDP and the other variables. Conclusions and policy recommendations were then made to the government in line with the results of the model estimation. Top of the list is the investment in the natural gas utilization network to increase natural gas consumption which would reduce the impact of other fossil fuels as well as serve as a transition fuel in our effort towards sustainable energy sources.

1.0 INTRODUCTION

According to the EIA, 2019, natural gas is a fossil formed deep beneath the earth's surface which contains many components, the largest component of which is methane (a compound of four hydrogen atoms and one carbon atom). Natural gas has two major components, the associated gas (part of the oil production process) and the non-associated gas (produced separately from oil), both of which form the natural gas accumulation. Nigeria has a proved reserve value of 188.8 Tcf which is 2.7% of the world's total proved reserves (BP, 2019). Production wise, Nigeria had an annual production rate of 1.74 Tcf for the year 2018, which is 1.3% of the total world daily production (BP, 2019). Considering annual consumption values, Nigeria utilized, for the year 2018, 0.68 Tcf which is 0.5% of the global annual consumption (EIA, 2019). Combining the figures above for natural gas in Nigeria gives a reserve production ratio of 108.5 years. For crude oil data obtained from OPEC, 2019, the proved reserves value is 36.97 Bbbl (3.1% of OPEC), the 2018 annual production value of 1.72 Bbbl (5.4% of OPEC); a reserve to production ratio of 24.75 years. Comparing both figures, it is then logical to state that Nigeria is a predominantly gas province and not an oil one. According to the Nigeria Gas Policy, 2017, Nigeria is a gas play, not an oil play.

As an economy that is miles away from achieving its full potential, Nigeria is in dire need of energy source to drive its industrial development. This energy requirement is across the different forms of final energy forms. Power is required for heating and utility functions and majorly for electricity generation. Of all the different fossil energy primary sources, natural gas provides the least amount of environmental degradation (represented by greenhouse carbon iv oxide production). According to the EIA, 2019, natural gas produces 117.0 lbs of carbon (iv) oxide per million btu (British thermal units – a unit for energy). For a comparison, diesel heating oil produces 161.3 lbs whereas anthracite coal produces 228.6 lbs. This comparison does not take into account other harmful and noxious gases that other forms of energy have (such as oxides of sulphur and nitrogen) which are either inexistent or insignificant in natural gas.

For the carbon dioxide production consideration, Nigeria produced 96,281 kilotons while the total global carbon dioxide production as at 2018 was 36.14 million kilo tons (EIA, 2019). The carbon dioxide values in the previous statements which show an increasing trend from the 1960s and would continue to increase with the combination of energy sources being employed globally. Considering these information, Nigeria has a need to determine the need to produce cleaner energy sources for two major reasons.

The first part is Nigeria is predominantly a gas enclave; hence there is a need to determine the best way of maximising the energy output of natural gas in order to achieve economic development (improved GDP). Also, with increasing trend of carbon dioxide production from fossil fuels, there is also the need to reduce the quantity being produced while making efforts to achieve an improved economic performance. So, the relationship between the three variables of natural gas consumption, economic growth and carbon dioxide production would have to be estimated. This estimation would then be applied in prediction of future relationships which could be further applied in making policy decisions.

The relationships between these parameters over the years have been considered to either have been unidirectional or bi-directional (or multidirectional). The unidirectional, simpler models such as the ARDL (autoregressive distributed lag) assume a single direction in the relationship. This is the assumption that energy consumption results in economic growth and the carbon dioxide emission. A reverse relationship was not pursued in earlier efforts. However, this is a simplified approach which does not reflect the real-life situation of multidirectional relationships. These relationships have both correlation and causality to be considered. This study would apply a model that would explore both the bidirectional relationship as well as the causality question. This is because a positive correlation does not imply causality.

The relationship between the different parameters being considered must be rooted in economics – it must be based on a sound economic theory. There is the neutral hypothesis which makes the assumption that there is no causal relationship between natural gas consumption and economic growth. The conservation hypothesis considers a unidirectional causality from natural gas consumption to economic growth. The same hypothesis is applied in assuming a unidirectional causality from economic growth to natural gas consumption. The final hypothesis to be considered is the feedback hypothesis that assumes a bidirectional relationship between natural gas consumption and economic growth. The hypotheses above are consistent with views expressed by Dogani and Akcicek (2015). Sica and Senturk (2016) also made similar observations. The same relationships specified above between the consumption of natural gas and economic growth would then have to be exploited for natural gas consumption and carbon dioxide emission; and economic growth and carbon dioxide emission.

The ability to explore these multidirectional relationships is afforded by the vector models of Vector Autoregressive (VAR) and the Vector Error Correction (VEC) models. As would be determined later in the study, the choice of either of this system of matrix models is dependent on the nature of the relationship between the parameters. Long run relationships apply the VEC model while short run relationships use the VAR model. Studies with these models have been done for total energy consumption, oil and gas consumption, electricity consumption, etc and their relationships to economic growth and sustainable development. This has been done for different countries or compared for different groups of companies as part of a panel investigation.

This study, therefore, aims to add to the body of knowledge by specifically exploring a multidirectional relationship between natural gas consumption, economic growth and sustainable development in Nigeria. The aim of which is to maximize Nigeria's potential in terms of sound policies as an emerging gas province.

2.0 REVIEW OF LITERATURE

Multiple researches have been done in the area of model estimation for the relationship between the consumption of different forms of energy and economic development. Some of the studies which covered different regions of the world, included elements of sustainable development (carbon dioxide emission) in their list of variables studied. Also, some studies further disaggregated the different energy forms into various components and studied them individually with respect to economic growth and/or sustainable development. Some of the unbundled forms of energy included crude oil, natural gas and electricity. Some of the studies reviewed are contained below.

Dhungel (2008) studied the relationships between per capita consumption of coal, electricity, oil commercial energy; and the per capita real gross domestic product (GDP) in Nepal. The study employed the use of co-integration and vector error correction models, and the results obtained pointed out a unilateral causality relationship from the consumption of the different energy forms to the per capita GDP. On the other hand, however, the study obtained a unilateral relationship emanating from the per capita GDP in the direction of the per capita electricity consumption. This study assumed a possible multilateral relationship between the variables (hence the need for co-integration tests) and it also determined the existence of a long term relationship hence the use of the vector error correction (VEC) models. Similar results were also obtained by Aktas and Yilmaz (2008) for a study carried out in Turkey.

Kalyoncu et al (2013) investigated the relationship between energy consumption and economic growth in Georgia, Azerbaijan, and Armenia. The study applied the Engle-Gragner cointegration and Gragner causality tests in the causal relationship analysis of the identified variables. For Georgia and Azerbaijan, no cointegration existed between the two variables. However, for Armenia, the research results point at a unilateral causality from per capita GDP to per capita energy consumption. This result is in line with the studies of Dhungel (2008) who performed his studies in Nepal (discussed above).

Sica and Senturk (2016) researched the causality relationship between electrical power consumption and economic growth in Italy and Turkey. The study employed the frequency domain causality (FDC) approach with the reason that previous studies mostly focused on the directionality of causality whereas the FDC consisted of short, medium and long-term causality analyses. Their results pointed out that electricity consumption in Italy causes economic growth in the short, medium and long terms (conservation hypothesis). For Turkey, they observed no causality relationship being shown between electricity consumption and economic growth (neutral hypothesis) while there is a unidirectional relationship emanating from economic growth to electricity consumption (conservation hypothesis).

Sharmin and Khan (2016) examined the causal relationships between energy consumption, income and energy prices for twenty-six African countries. The study applied the Johansen's cointegration test and the vector error correction (VEC) model for these countries which were selected because they had at least twenty-five years of data in the variables being investigated. The results were expectedly mixed for the countries selected in line with the diverse results of the studies earlier performed in this area. Some results were unidirectional, some were bi-directional, and short, medium and long term relationships were determined. In all, the authors suggested that the eventual policies that ensue from the study should incorporate the peculiar situation of each in order to be robustness.

Bayat et al (2017) did a slightly different study by investigating the causation linkage between economic growth and electricity consumption in Turkey followed by the application of shocks. Electricity consumption was used as an indicator of energy consumption. They employed the then-developed asymmetry causality analysis developed by Hatemi-J and Roca (2014) in the analysis of the Turkish economy. The results obtained implied a bi-directional relationship between economic growth and electricity consumption. The asymmetric linkage between the variables was shown in the fact that an increase in electricity consumption does not affect economic growth positively, but a decrease in electricity consumption created a decrease in economic growth. On the other hand, economic growth affected electricity consumption in both positive and negative shocks.

Some of the studies reviewed added carbon dioxide emission as a variable to the study. Among them is Kumar (2011) who studied the relationship between energy consumption, carbon dioxide emission and economic growth in India. With the application of the Gragner Approach in the VAR framework, he established a causality link between energy consumption and economic growth. The study also determined a positive impact of energy consumption on carbon dioxide emissions and gross domestic product (GDP). Other studies also determined a multidimensional relationship between the variables. Arouri et al (2012) investigated data from the middle east and north Africa (MENA) while Hezareh (2017) studied twenty-two (22) D8 countries. These studies obtained multidimensional relationships between the variables analysed.

Some studies have been performed on the Nigeria economy and they reveal the same trend of relationship determined in other economies. Kehinde et al (2012) observed a causal relationship between crude oil consumption and economic growth. The direction of this was determined to be stemming from crude oil consumption towards GDP. Akpan (2012), Ejuvebekpoko (2014) and Onolemhemhen (2017) studied the Nigerian economy with different models to determine some levels of multidimensional relationships between the variables of energy consumption, economic growth and carbon dioxide production. It should be noted that these studies used energy consumption directly or with different substitutes such as oil consumption and electricity consumption.

The gap that exists therefore is the area of a gas consumption study for the Nigerian economy, bearing in mind Nigeria's position as an emerging gas province. Also, the need to study the multidimensional relationships that exist in real life without the arbitrary designation of variables as either endogenous or exogenous without a full empirical backing. It is in these two areas that this study intends to contribute to the body of knowledge.

3.0 METHODOLOGY

3.1 THE VECTOR AUTOREGRESSIVE (VAR) MODEL

According to Bjorland (2000), the failures of the classical econometric models to predict the oil price crises of the 1970s, the complicated nature of the models and the restriction of variables as either exogenous or endogenous has led to the choice of the vector autoregressive (VAR) model by many economists. The VAR model is an adaptation of the single variable autoregressive model to multivariable time series data. It is a multi-equation system without clearly marked-out endogenous and exogenous variable. That is, all the variables are treated as endogenous variable in the system and, there is one equation as each variable as the dependent variable. The VAR model is useful in the description of dynamic behaviour that exists in economic and financial time series data and also useful in forecasting. Also, VAR model is the model of choice in the analysis of system response to different shocks/impacts. As a result it is very useful in the model-based forecast of macroeconomic variables such as GDP, money supply, unemployment, etc.

When specifying the VAR model, the choice of the parameters to be included in the model must be based on a justifiable economic theory. According to Clements and Mizon (1991) and Canova (1995a,b), the process of determining which variables to include (called marginalization) must be done with respect to the variables that are potentially relevant. The proper specification of the lag lengths and dynamic specification of the model must be well-done.

The basic VAR model is given as:

$$Y_t = a + A_1 Y_{t-1} + A_2 Y_{t-2} + A_3 Y_{t-3} + \dots + A_p Y_{t-p} + \varepsilon_t \quad \dots\dots (1)$$

where:

$Y_t = (y_{1t}, +y_{2t}, \dots, y_{nt})$: an (nx1) vector of time series variables.

a: an (nx1) vector of intercepts

A_i (i = 1,2, 3, …, p): an (nx1) vector of unobservable i.e. zero mean error term (white noise)

Example for the bivariate Model is given below:

$$\begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} + \begin{bmatrix} b_{11}^1 & b_{12}^1 \\ b_{21}^1 & b_{22}^1 \end{bmatrix} \begin{bmatrix} y_{1t-1} \\ y_{2t-1} \end{bmatrix} + \begin{bmatrix} b_{11}^2 & b_{12}^2 \\ b_{21}^2 & b_{22}^2 \end{bmatrix} \begin{bmatrix} y_{1t-2} \\ y_{2t-2} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \dots \dots (2)$$

Or:

$$y_{1t} = a_1 + b_{11}^1 y_{1t-1} + b_{12}^1 y_{2t-1} + b_{11}^2 y_{1t-2} + b_{12}^2 y_{2t-2} + \varepsilon_{1t} \dots \dots (3)$$

$$y_{2t} = a_2 + b_{21}^1 y_{1t-1} + b_{22}^1 y_{2t-1} + b_{21}^2 y_{1t-2} + b_{22}^2 y_{2t-2} + \varepsilon_{2t} \dots \dots (4)$$

Considering a very simple bivariate model with no intercepts in order to derive the formulas without complications:

$$\begin{bmatrix} y_t \\ x_t \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ x_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{y,t} \\ \varepsilon_{x,t} \end{bmatrix} \dots \dots (5)$$

Where $\varepsilon_{y,t}$and $\varepsilon_{x,t}$ are two white-noise variables (correlated or uncorrelated)

We now express y_t as a function of y_{t-1} and $\varepsilon_{y,t}$ and $\varepsilon_{x,t}$

Solving the initial equation for x_{t-1};

$$x_{t-1} = (1/a_{12})y_t - (a_{11}/a_{12})y_{t-1} - (1/a_{12})\varepsilon_{y,t} \dots \dots (6)$$

Substituting this into equation (5)

$$x_t = (a_{22}/a_{12})y_t + (a_{21} - a_{22\frac{a_{11}}{a_{12}}})y_{t-1} - \frac{a_{22}}{a_{12}}\varepsilon_{y,t} + \varepsilon_{x,t};\ \ a_{12} \neq 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(7)$$

Replacing the t by t+1 in Equation (5), we obtain,

$$x_t = (a_{22}/a_{12})y_t + (a_{21} - a_{22\frac{a_{11}}{a_{12}}})y_{t-1} - \frac{a_{22}}{a_{12}}\varepsilon_{y,t} + \varepsilon_{x,t};\ \ a_{12} \neq 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(8\ a)$$

$$Y_t = a + A_1Y_{t-1} + A_2Y_{t-2} + A_3Y_{t-3} + \ldots + A_pY_{t-p} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(8b.)$$

These variable are then replace with the variables under investigation which are GDP, natural gas consumption and carbon dioxide emission. This is observable from equations (9) below.

3.2 THE UNIT ROOT TEST (STATIONALITY)

The methodology which adapts the vector autoregressive model (VAR) requires that the variables have to be trend stationary. Generally, it has been observed in studies that most of the data series are not stationary at level I(0), but attain stationarity after first differencing I(1) (Abimelech et al., 2017).

The study to determine the unit root makes use of the augmented Dickey-Fuller test (ADF) Test.

3.3 CO-INTEGRATION TEST

Co-integration test is needed when the variables are not stationary at levels. If the time series variables are stationary at levels, then co-integration test is not required. This shows that the long run effect is not different from the short run effect. Series that are non-stationary that become stationary when first differenced, is said to be integrated of order 1.

Two prominent approaches for the co-integration test are the Engle & Granger(1987) two-step process.

The underlying hypotheses are:

(eia Beta, 2019)

HJ: $r = 0 \Longrightarrow No\ cointegration \Longrightarrow No\ long\ run\ relationship$

H': $r \neq 0 \Longrightarrow Cointegration\ exists \Longrightarrow long\ run\ relationship\ exist$

3.4 GRAGNER CAUSALITY TEST

The study employs the granger causality test to examine whether the past values of a variable help in predicting current changes in the unrestricted VAR model (Granger, 1969).

3.5 DATA SOURCES

The dataset for the study uses the gross domestic product (GDP) as a substitute for economic growth, natural gas consumption, and carbon dioxide (CO2) emission for Nigeria. CO2 emission is in kilo-tonnes, energy consumption is in quadrillion BTU, GDP is measured is presented in USD. The data for GDP was obtained from the International Bank for Reconstruction and Development (IBRD), World Bank, from 1980 to 2016, a total of 37 observations. The period and frequency of the chosen data set adapted for the study was based on the need to balance the number of degrees of freedom with data availability. The data for natural gas consumption and carbon dioxide emission was sourced from the American Energy Information Administration (eia). The data is presented graphically below.

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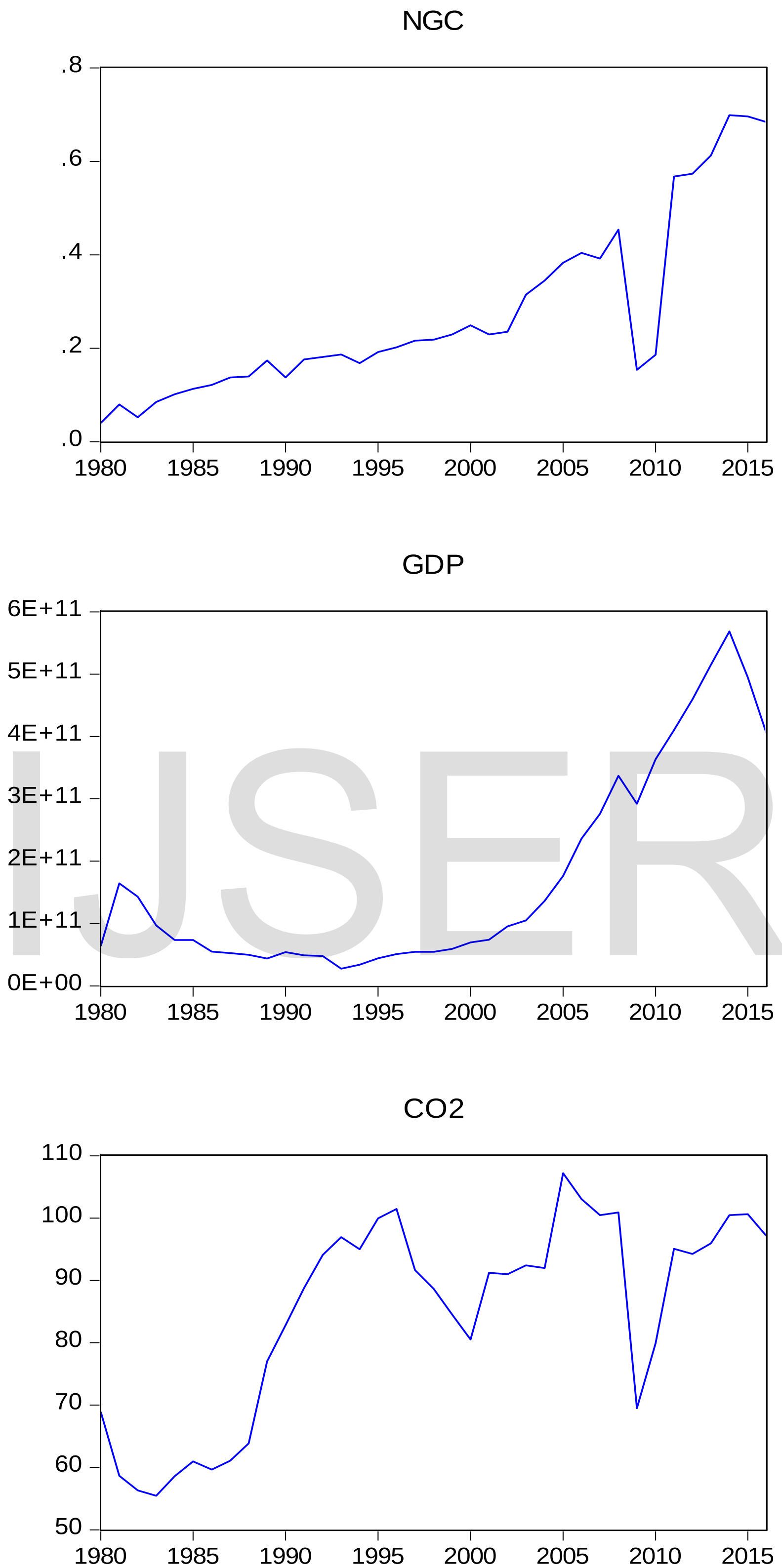

Figure 1: Graphical Representation of Natural Gas Consumption, GDP and CO2 Emission Data for Nigeria from 1980 – 2016 (IBRD & EIA, 2019).

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In order to smoothen the data and also to be able to interpret the results in terms of elasticities, the data were then converted to log forms. The log forms of the data are presented below.

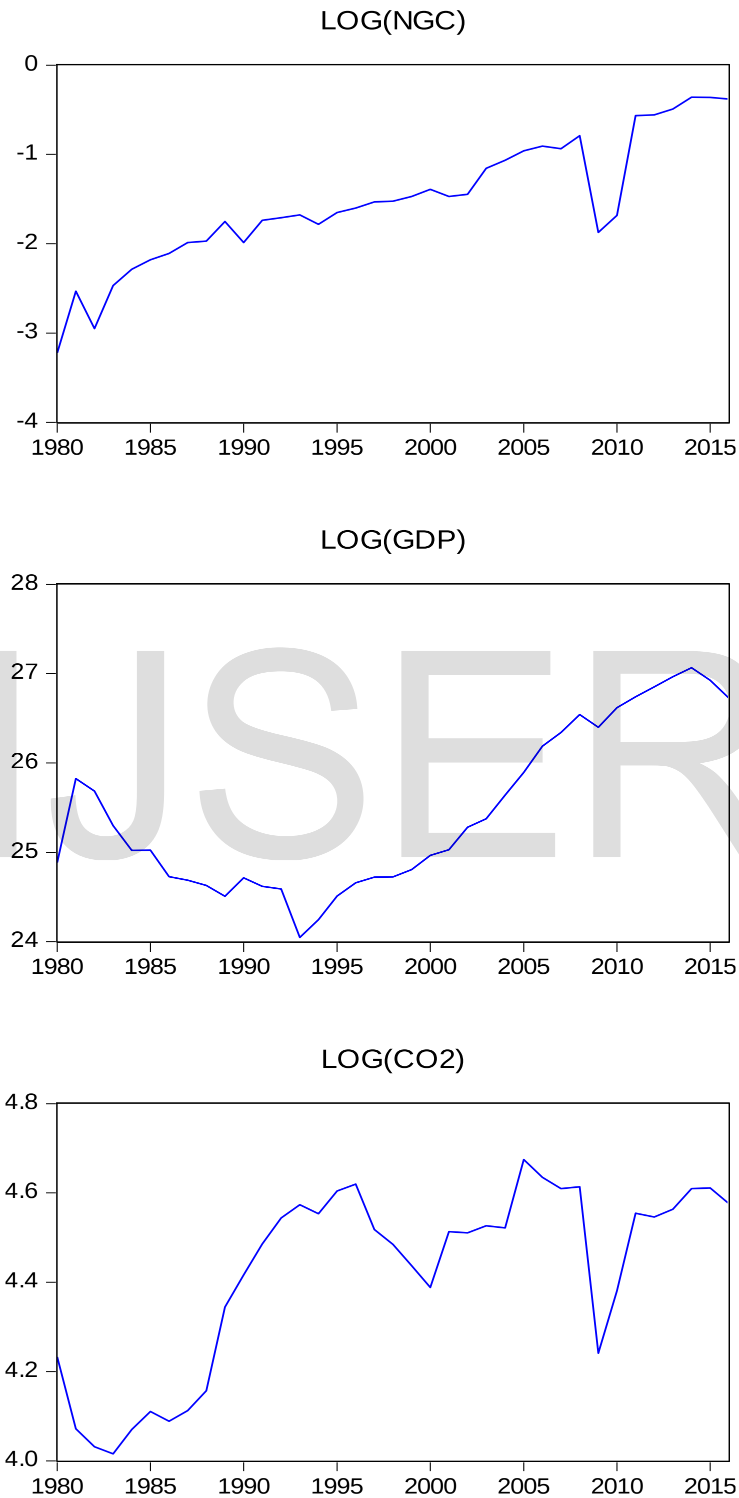

Figure 2: Graphical Representation of logs of Natural Gas Consumption, GDP, and CO2 Emission Data for Nigeria from 1980 – 2016 (IBRD & EIA, 2019).

3.6 DESCRIPTIVE STATISTICS

Table 1: Descriptive Statistics for Nigeria Natural Gas Consumption, GDP and CO2 Data

	LOG(NGC)	LOG(GDP)	LOG(CO2)
Mean	-1.527512	25.44519	4.420249
Median	-1.600070	25.02774	4.513143
Maximum	-0.358304	27.06627	4.674830
Minimum	-3.224240	24.04658	4.015374
Std. Dev.	0.708939	0.909842	0.205973
Skewness	-0.165812	0.453971	-0.786779
Kurtosis	2.716098	1.785382	2.132801
Jarque-Bera	0.293803	3.545304	4.976684
Probability	0.863379	0.169882	0.083048
Sum	-56.51795	941.4720	163.5492
Sum Sq. Dev.	18.09338	29.80124	1.527299
Observations	37	37	37

The first and second moment of the distributions, mean and standard deviation suggest that the mean are not zero and evidence of deviation from the mean. This is because both values are not zero. The log (GDP) is the most volatile series when compared with other variables in consideration; this is because of the value of the standard deviation. The log(Natural Gas consumption) and log(CO2 emission) series are skewed to the left based on the value of the skewness while the log(GDP) is skewed to the right. The descriptive statistics shows that there might be presence of asymmetry in the probability distribution for all series around the mean. The series does not exhibit fat tails, indicating that they are not leptokurtic since kurtosis is less than 3. This also indicates that changes are not extreme for the variables in consideration. The

Jarque-bera test indicates that the series are normal for log(GDP) and log (Natural Gas Consumption) since there is no statistical significance among series.

3.7 STATIONALITY ANALYSIS

Table 2: Augmented Dickey-Fuller Unit Test Results.

	Level			First Differenced			
Variable	**None**	**Constant**	**Constant + Trend**	**None**	**Constant**	**Constant + Trend**	**I(0) or I(1)**
log(ngc)	-2.235105**	-2.069441	-2.985708	-5.102584***	-2.725769*	-2.286987	I(1)
log(gdp)	1.211800	-0.310002	-1.376615	-6.379518***	-6.257708***	-7.072853***	I(1)
log(co2)	0.516523	-1.467571	-2.083673	-6.003912***	-6.045920***	-5.986398***	I(1)

Table 2 above displays the reported stationarity test for the variables for level and first differenced series for natural gas consumption, economic growth and carbon dioxide emission in Nigeria. The Augmented Dicker-Fuller test for most of the data series under the category; none, constant, constant + trend fails to reject the unit root null hypothesis for the trend stationary model for the variables except for log(ngc) under the 5% significance level that rejected the H0 for the alternative trend for the model. If the null hypothesis were all rejected, the data would be stationary at level. That would mean that only long run estimates determined by the model. There would be no short run effect.

However, when the series were first differenced, the tests results show that non-stationary variables became stationary after taking the first order difference or I(1). From the results above, the variables (or series) are not stationary at level, but are stationary at first difference, and hence there is a need to carry out a cointegration test. This test would determine whether both long-run and short-run effects exist. The results of the cointegration test would determine which effects would be explained by the model to be generated. The cointegration analyses are performed below.

3.8 CO-INTEGRATION ANALYSIS

The Johansen co-integration test was used to determine the extent of cointegration between the variables in the system. This test would determine if short-run or long run estimates would be estimated by the model to be derived. The first step is to determine the lag length to be used in the co-integration analysis. Loading the variables in the VAR model and selecting a maximum lag length of four (4) in the lag selection criteria, the lag length that is significant is lag length of one (1). At these lag length, the Akaike information criterion (AIC), the Schwarz information criterion (SC) and Hannan-Quinn information criterion (HQ) were all significant at the lag length of one (1). That is the lag length that was applied in the co-integration analysis.

Table 3: Johansen Co-integration Test Results.

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.385307	29.29228	29.79707	0.0571
At most 1	0.295432	12.26015	15.49471	0.1449
At most 2	0.000120	0.004185	3.841466	0.9471

From the Johansen co-integration test results above, the trace statistic values were all less than the critical values. For example, the values (29.79707 < 29.29228), (12.26015 < 15.49471), and (0.004185 < 3.841466). With this values being less than the critical values, the Ho hypothesis of no co-integration is not rejected which means a short-run relationship exists in the model. The model that would be specified for this relationship is a short-run model.

4.0 EMPIRICAL RESULTS AND DISCUSSIONS

4.1 MODEL LAG SELECTION CRITERION

The VAR model lag selection criterion is the lag length to be applied for the estimation of the model. A maximum lag length of four (4) was selected and the length with the most significant criterion was obtained. There was no clear rule for the selection of lag lengths, but it is suggested that a maximum lag length of four (4) is recommended for short-run models. The table below shows the results from the lag length selection process.

Table 4: Lag Length Selection Criteria (Eviews 9 Computations).

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-27.12327	NA	0.001246	1.825652	1.961699	1.871428
1	57.51217	148.7532*	1.28e-05*	-2.758313*	-2.214129*	-2.575212*
2	60.94249	5.405361	1.82e-05	-2.420757	-1.468434	-2.100329
3	64.50493	4.965826	2.63e-05	-2.091208	-0.730747	-1.633454
4	66.51833	2.440486	4.33e-05	-1.667778	0.100822	-1.072698

From the result above, the Sequential Modified LR test (LR), the Final Prediction Error (FPE), Akaike information criterion (AIC), the Schwarz information criterion (SC) and Hannan-Quinn information criterion (HQ) were all significant at the lag length of one (1). That is the lag length that would be selected for the model estimation. That is the lag selection criteria to be applied to the model estimation.

4.2 GRAGNER CAUSALITY ANALYSIS

The Gragner causality test run for the system shows the following results below with the null hypothesis being that these variables do not Gragner cause the other. If the probabilities are significant, then the null hypothesis would have to be rejected.

Table 5: Gragner Causality Analysis (Eviews 9 Computations).

Null Hypothesis:	Obs	F-Statistic	Prob.
LOG(NGC) does not Granger Cause LOG(GDP)	35	4.47015	0.0200
LOG(GDP) does not Granger Cause LOG(NGC)		0.79923	0.4590
LOG(CO2) does not Granger Cause LOG(GDP)	35	3.61474	0.0392
LOG(GDP) does not Granger Cause LOG(CO2)		0.09339	0.9111
LOG(CO2) does not Granger Cause LOG(NGC)	35	1.70745	0.1985
LOG(NGC) does not Granger Cause LOG(CO2)		1.14778	0.3309

From the relationship above, the null hypothesis is rejected for log(NGC) Gragner causing log(GDP). This means that GDP growth Gragner causes Natural Gas Consumption. Also the table above shows that GDP growth Gragner causes carbon dioxide emission as the null hypothesis of carbon dioxide emission causing GDP growth is rejected. There is no significant relationship between direction causality for the relationship between the carbon dioxide emission and natural gas consumption. In terms of causality alone, the results obtained above make sense, economic theory-wise. This is because the unidirectional causality relationship between GDP growth and natural gas consumption is consistent with conservation theory of economics. The same holds for the relationship between GDP growth and carbon dioxide consumption.

On the other hand, the relationship between natural gas consumption and carbon dioxide emission is consistent with the neutral economic theory.

However, the causality analysis performed above only gives the direction of the relationship. The value of the magnitude of these relationships is only determined by the analysis of the sign and magnitude of the coefficients in the VAR model. This would be done in the next section. And, due to the fact that the model is expressed in terms of logarithmic relationships, the elasticities of these relationships can be estimated.

4.3 VAR ESTIMATES

The VAR estimates for the system is as contained below and can be re-written in terms of the coefficients of the relationships and their levels of significance.

Table 6: VAR System Coefficients and Probabilities.

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	1.049525	0.062782	16.71701	0.0000
C(2)	-0.250581	0.127859	-1.959818	0.0529
C(3)	0.915388	0.353466	2.589750	0.0111
C(4)	-5.640319	2.873381	-1.962955	0.0525
C(5)	0.138595	0.079028	1.753744	0.0827
C(6)	0.618462	0.160945	3.842678	0.0002
C(7)	0.512491	0.444931	1.151843	0.2522
C(8)	-6.300721	3.616921	-1.742013	0.0847
C(9)	-0.034280	0.025031	-1.369530	0.1740
C(10)	0.088270	0.050976	1.731582	0.0866
C(11)	0.688497	0.140923	4.885610	0.0000
C(12)	2.393796	1.145590	2.089576	0.0393
Determinant residual covariance		1.56E-05		

Equation: LOG(GDP) = C(1)*LOG(GDP(-1)) + C(2)*LOG(NGC(-1)) + C(3) *LOG(CO2(-1)) + C(4)
Observations: 36

R-squared	0.938642	Mean dependent var	25.46074
Adjusted R-squared	0.932890	S.D. dependent var	0.917747
S.E. of regression	0.237748	Sum squared resid	1.808771
Durbin-Watson stat	1.543752		

Equation: LOG(NGC) = C(5)*LOG(GDP(-1)) + C(6)*LOG(NGC(-1)) + C(7) *LOG(CO2(-1)) + C(8)
Observations: 36

R-squared	0.810632	Mean dependent var	-1.480381
Adjusted R-squared	0.792879	S.D. dependent var	0.657583
S.E. of regression	0.299270	Sum squared resid	2.865993
Durbin-Watson stat	2.105983		

Equation: LOG(CO2) = C(9)*LOG(GDP(-1)) + C(10)*LOG(NGC(-1)) + C(11) *LOG(CO2(-1)) + C(12)
Observations: 36

R-squared	0.807187	Mean dependent var	4.425458
Adjusted R-squared	0.789111	S.D. dependent var	0.206408
S.E. of regression	0.094788	Sum squared resid	0.287511
Durbin-Watson stat	2.048009		

Source: Author.

The equations in the system are explained individually below as follows:

$$Log\ GDP = 1.049525^{***}\ Log\ GDP_{-1} - 0.250581^{*} Log\ NGC_{-1} + 0.915388^{**}\ Log\ CO2_{-1} - 5.640319^{*} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(9)$$

From the equation (9) above, the there is a negative effect of natural gas consumption on the GDP. This means that as natural gas consumption increases, the GDP decreases. This relationship could be explained in terms of the gas consumption infrastructure available in the country at the moment. Most of the infrastructures available are geared towards oil and not in terms of gas production.

Also, there is a positive relationship between the carbon dioxide emission and the GDP of the country. This is because the GDP as it is now is sustained by mostly oil-type fossil fuels which emit a lot of carbon dioxide.

$$Log\ NGC = 0.138595^{*}\ Log\ GDP_{-1} + 0.618462^{***} Log\ NGC_{-1} + 0.512491\ Log\ CO2_{-1} - 6.300721^{*} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(10)$$

From the equation 10 above, natural gas consumption has a positive relationship with the GDP. This means that an increase in GDP would result in an increase in natural gas consumption. The relationship is a slightly significant one (at 10%) which shows that this is not a very strong relationship. This slight relationship is in line with the Gragner Causality analysis which shows that natural gas consumption does not Gragner cause GDP. On the other hand, the equation shows a direct positive relationship between the emission of carbon dioxide and natural gas consumption. However, the absence of significance in the coefficients of this relationship nullifies the effect. This assertion is in line with the Gragner Causality Analysis that natural gas consumption does not Gragner Cause carbon dioxide emission and vice versa. This is related to the infrastructures in place not being designed for the maximal utilization of natural gas resources, and the fact that carbon dioxide emission by natural gas consumption is not significant.

$$Log\ CO2 = -0.034280\ Log\ GDP_{-1} + 0.088270^{*} Log\ NGC_{-1} + 0.688497^{***}\ Log\ CO2_{-1} + 2.393796^{**} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(11)$$

From the equation (11) above, it would be observed that there is no significance in the coefficient of GDP with respect to CO2. This means that GDP does Granger cause CO2 emission. This is in agreement with the Gragner Causality Test performed earlier in this study. The carbon dioxide emission parameter is slightly affected by natural gas consumption. The significance of 10% underscores that this is not a strong relationship which agrees with the Gragner Causality Test which states that CO2emission does not Gragner cause natural gas consumption.

4.4 IMPULSE RESPONSE FUNCTION

The impulse response function is used to determine the response of a variable when a shock of one standard deviation is applied to itself or to another variable. This could be used to determine how the variable would respond to internal or external shocks of related variable in the vector autoregressive system.

For the results presented in the table below, the periods 1 -3 are considered short term, the periods 7-10 are considered long term while the periods in between are considered medium term. For the effect of shocks on the GDP, would suffer a dip due to natural gas shocks in the short term while the medium and long terms show an increase with the rates of increase gradually increasing from the medium term to the long term. This aligns with the slightly significant values obtained in the model estimation. It is also consistent with the facts on ground in the sense that the low infrastructure and high cost of natural gas utilization makes its effect on the GDP negative in the in the short term but the effect would improve in the medium and long term. This is because the initial huge investment that would need to be made prior to the utilization of natural gas (such as transmission networks for supply and construct gigantic turbines for utilization) would temporarily result in a dip in productivity. On the other hand, the effect of carbon dioxide would increase in the short term, but become constant in the medium and long term. The explanation is that the effect of carbon dioxide from other fossil fuels would affect the GDP in short term, but with the use of more environmentally-compliant fuels in the long term would even out the effect.

For natural gas utilization, when compared against GDP shocks, there is an increase in the short term but this evens out in the medium term and the long term. The explanation is that there would be an increase in the short term in order to be able to sustain the level of GDP, and this becomes constant in the medium and long term.

For carbon dioxide emission, there is a reduction of the value with respect to GDP shocks in the short term while this becomes constant in the medium and long term. With respect to natural gas utilization, there is a slight increase in the short term, followed by a reduction in the value in the long term. The explanation after a slight kick in the short term, the effect of carbon dioxide emission is reduced in the medium and long term by natural gas consumption shocks.

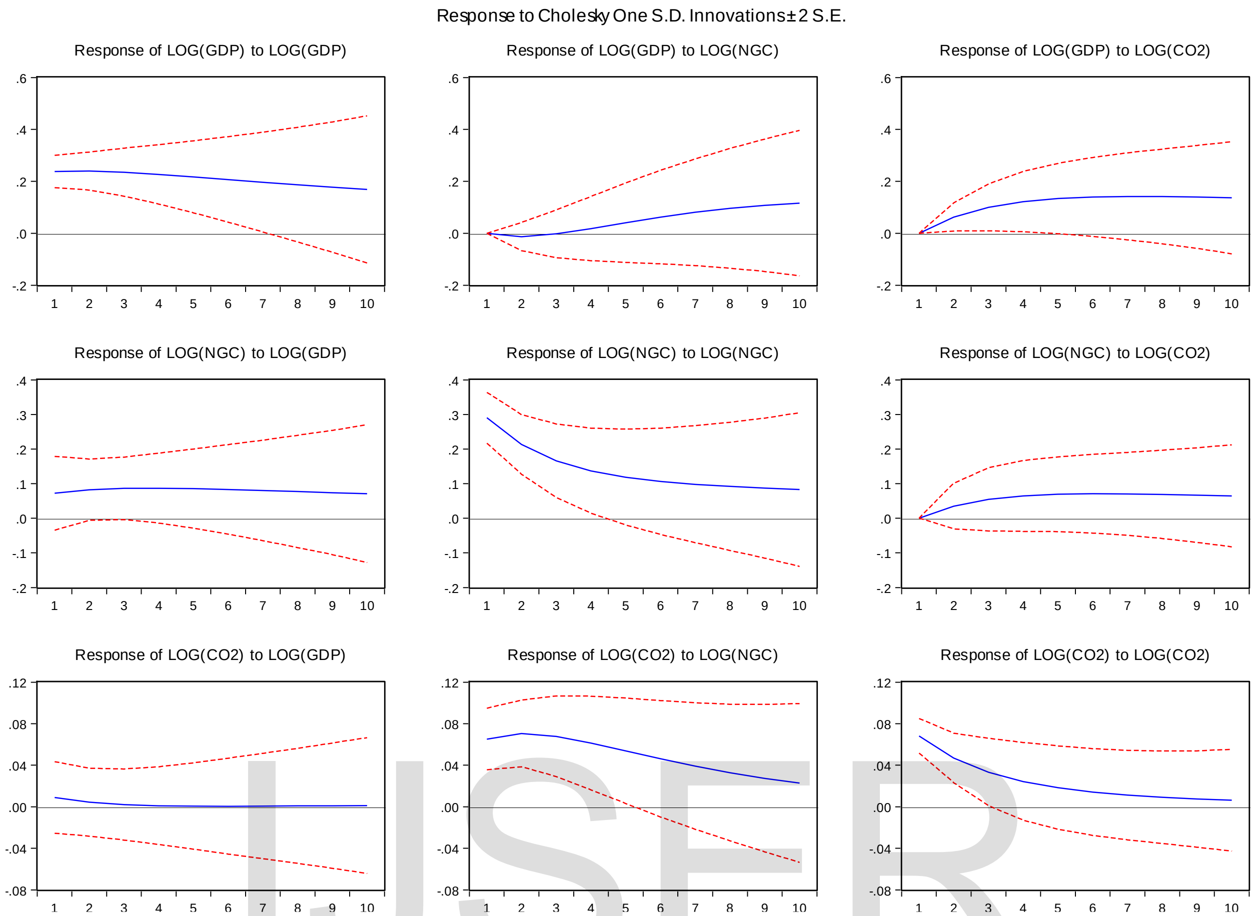

Figure 3: Impulse Function Analysis

4.5 VARIANCE DECOMPOSITION ANALYSIS

The variance decomposition analysis shows the percentage of the variance error that impacts on its own shocks and other variables in the unrestricted vector autoregressive (VAR) model. It shows how these variables contribute to the observed effect in the short, medium and long term. The graphs and table below explain how this varies during the forecast period.

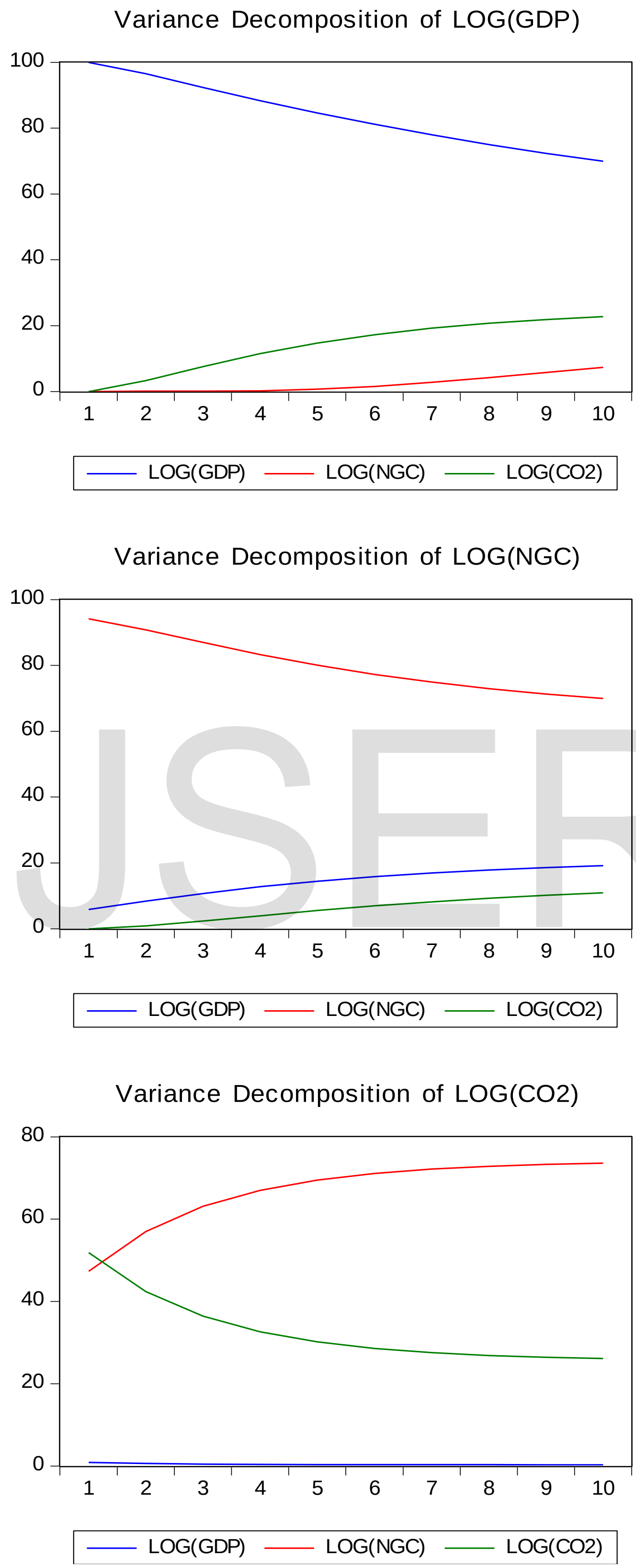

Figure 4: Variance Decomposition Analysis

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Table 7: Variance Decomposition Analysis Results.

Period	S.E.	LOG(GDP)	LOG(NGC)	LOG(CO2)
Variance Decomposition of LOG(GDP):				
1	0.237748	100.0000	0.000000	0.000000
2	0.343502	96.54773	0.145603	3.306669
3	0.427906	92.33217	0.097482	7.570345
4	0.499596	88.32516	0.197575	11.47727
5	0.562324	84.61335	0.674579	14.71207
6	0.618331	81.16614	1.562928	17.27093
7	0.669024	77.97011	2.785271	19.24462
8	0.715282	75.02892	4.226700	20.74438
9	0.757669	72.34827	5.777258	21.87447
10	0.796562	69.92764	7.349569	22.72279
Variance Decomposition of LOG(NGC):				
Period	S.E.	LOG(GDP)	LOG(NGC)	LOG(CO2)
1	0.299270	5.807993	94.19201	0.000000
2	0.378038	8.356832	90.78743	0.855737
3	0.425302	10.71056	86.97952	2.309925
4	0.459774	12.73614	83.31842	3.945442
5	0.487457	14.41733	80.05705	5.525616
6	0.510804	15.79053	77.26248	6.946988
7	0.531011	16.90708	74.91193	8.180992
8	0.548758	17.81653	72.94908	9.234389
9	0.564482	18.56115	71.31126	10.12759
10	0.578495	19.17502	69.94076	10.88421
Variance Decomposition of LOG(CO2):				
Period	S.E.	LOG(GDP)	LOG(NGC)	LOG(CO2)
1	0.094788	0.876810	47.29888	51.82431
2	0.127216	0.602477	56.98801	42.40951
3	0.147966	0.463870	63.12528	36.41085
4	0.162048	0.390160	67.00359	32.60625
5	0.171717	0.348484	69.48351	30.16801
6	0.178363	0.323778	71.09012	28.58610
7	0.182928	0.308927	72.14205	27.54902
8	0.186064	0.300361	72.83602	26.86362
9	0.188220	0.296117	73.29602	26.40787
10	0.189709	0.294988	73.60169	26.10333
Cholesky Ordering: LOG(GDP) LOG(NGC) LOG(CO2)				

From the results obtained above, it is evident that for the GDP in the short term, 96% of the change comes from GDP shocks itself, about 4% from carbon dioxide emission and less than 1% from natural gas consumption. In the medium term, the ratios are 83% for GDP, 15% for carbon dioxide and 2% for natural gas consumption. In the long term, the relationships are 72% for GDP, 21% for carbon dioxide and 7% for natural gas utilization.

4.6 DISCUSSION OF RESULTS

The aim of the study is to study the relationships between the natural gas utilization, economic growth and carbon dioxide emission in Nigeria. The vector autoregressive (VAR) model was used based on the short term relationship which the collinearity test provided. The results obtained show a unidirectional causality relationship between the GDP and both the natural gas consumption and carbon dioxide emission. Also, the specification of the coefficients of the VAR systems shows a significant relationship between the carbon dioxide emitted and the GDP of the economy. This relationship is consisted with the fact that the economy is hugely dependent on the high carbon content fossil fuels (mostly crude oil) and its growth is highly tied to more carbon dioxide being produced. On the other hand, there is a weakly significant negative relationship between the GDP and the natural gas consumption. This is consistent with the lack of resources and the high cost of natural gas utilization. This points to the fact that in the short run, there would be a slight dip in the GDP while efforts are made to maximize the utilization of the natural gas fossil fuel. These relationships are spelt out in equation (9).

Equation (10) portrays the weakly significant relationship between the natural gas consumption and GDP. This relationship stems from the fact that the potentials of natural gas utilization are not being fully maximized in the economy as presently constituted. This can be changed with increased investment in the requisite domestic distribution infrastructures for natural gas. Equation (11) also shows a weakly significant relationship between carbon dioxide and natural gas consumption. It should be noted that despite the fact that natural gas is a cleaner fuel compared to other fossil energy sources, it still leads to the emission of carbon dioxide, though at a minimal quantity.

The results of the variance decomposition and impulse function curves also show a similar relationship as shown by the parameters of the VAR model.

5.0 CONCLUSIONS AND POLICY RECOMMENDATIONS

This study was aimed at generating a relationship for the GDP, the natural gas consumption and carbon dioxide emission for Nigeria using the unrestricted vector autoregressive (VAR) model. The model aimed at determining the dynamic relationships between these variables without explicitly designating anyone of them as the exogenous or endogenous variable. The aim of which is to have a more realistic representation of reality. The stationary analysis of the data and the collinearity test results pointed to a short term relationship hence the use of the VAR model. A more long term relationship would have resulted in the use of the vector error correction (VEC) model.

The Gragner causality tests yielded the results that GDP is Gragner caused by natural gas consumption and carbon dioxide emission. A unidirectional causality based on the conservation theory of economics was obtained in this case. The other variable exhibited a somewhat neutral theory of economics. However, when this Gragner Causality test is placed alongside the values and level of significance of the VAR model, it was observed that there are other important results to be noted.

It was observed that there was a significant relationship between carbon dioxide emissions and the GDP of the economy. This relationship is consistent with the level of dependence of the economy on the fossil fuels that produce relatively large quantities of carbon dioxide (such as oil). It shows that the more these fossil fuel sources are used to improve the economy, the more carbon dioxide that is produced. On the other hand, a weakly significant relationship was observed between the economy and natural gas consumption. This negative relationship is as a result of the present inability to maximise the potentials of natural gas in the economy due to the absence of infrastructure for its utilization and attendant high prices. Also, a large amount of investment in turbines would be required before natural gas can be maximised to drive the economy. From the policy standpoint, the aim should for the government to pursue a policy that would enable the maximization of natural gas utilization by the provision of enabling environment for private sector to participate in the transmission and distribution of gas to drive the economy. this would reduce unit cost prices. Also, there can incentives to large scale users to enable them acquire larger turbines in order to utilize more and improve their economy of scale. This would also engender sustainability as the effect of carbon dioxide emission would be tackled as well.

The study also produced a determination of a weakly significant relationship between natural gas consumption and GDP. This is also as a result of the low utilization being observed in the economy as presently constituted. This can be changed with increased investment in the requisite domestic distribution infrastructures for natural gas. The large scale production of carbon dioxide from the economy at the moment can also be improved by encouraging the conversion of fuel sources from oil to a cleaner alternative – natural gas. This could be a deliberative policy of using natural gas as a transition from oil in our efforts towards total dependence on renewable sources. This transition fuel policy could also be backed up by carbon taxes per unit quantity of carbon dioxide produced.

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