Pollutant Emissions, Energy Consumption and Economic Growth in Nigeria: A Multivariate Granger Causality Framework

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Abstract - **The study investigates the direction of causal relationships among emissions, energy consumption and economic growth in Nigeria using annual time series data for the period 1970-2013. The Johansen maximum likelihood cointegration tests indicate an existence of a unique cointegrating vector, and the normalized long run estimates shows that fossil fuel enhances carbon emissions whereas, clean energy source (electricity) mitigate the atmospheric concentration of CO_2 emissions. Similarly, the Wald exogeneity Granger causality test indicates an existence of unidirectional causation running from fossil fuel to CO_2 emissions and GDP per capita. Alternatively, non-fossil energy (electric power) causes more proportionate change in GDP per capita but our result could not establish any causal link between electric power and carbon emissions. Finally, charting a channel towards ensuring sustainable environment and economic development involves a progressive substitutability of clean energy sources for fossil consumption.**

Index Terms – CO_2 emissions, Johansen Cointegration, Granger Causality.

I. INTRODUCTION

Every developed and developing economy of the world desire a certain level of economic growth and sustainable development, but climate change and global warming remains the most common and controversial environmental issues in this modern age and poses threat to achieving this objective. This is because a sizable portion of the world's energy consumption need is met through fossil fuels. Therefore, increase in global trade and a rapid surge in economic activities around the world have caused a significant increase in carbon dioxide (CO_2) emission. As heavy use of energy and other natural resources cause environmental deterioration, also the gas emissions from fossil consumption increases the amount of carbon dioxide which harms the environment as well as inflicting irreparable damages on the atmosphere. This in turn leads to extremely risky climate changes such as drought, floods and rising sea levels. The global impacts are already apparent in increasing the frequency of extreme weather events, heightening storm intensity and reversing ocean currents. These changes, additionally, have significant impacts on the functioning of ecosystems, the viability of wildlife, and the wellbeing of humans. Meanwhile, the predictions by the Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) in 2007, has established that Africa is more vulnerable to global warming and climate change. This is evident in subsequent decline of water availability from 30 to 50 percent and decrease of 15 to 35 percent in agricultural yields across the continent in the last few years. Therefore, the complex nature of the relationship between pollutant emissions, energy consumption and economic growth process is a subject of greater inquiry among scholars and policy analysts since energy is considered as an important driving force of economic growth. The nature of this relationship in Nigeria like any other African countries becomes an important issue in this debate.

Why is Nigeria a suitable case study? And why should Nigeria be bothered? Nigeria as the giant of Africa has been on the focus of the world for its spectacular GDP growth as well as high energy demand growth in recent years. For instance, statistics from [1] have shown that the Nigerian economy has consistently grown by an average of over 6 percent in the last few years. The economy grew at 5.3 percent in 2011; 4.2 percent in 2012 and 7.4 percent in 2014; exceeding 5.5 percent in 2013. But in spite of this impressive consistent growth, the supply of electricity in Nigeria has remained irregular. This has ultimately led to the shift to alternative sources of power that has largely required burning of fossil fuels and subsequent increase in emission level. Therefore, there is no doubt that the current emission profile of Nigeria poses a significant challenge to the country`s economic growth.

Looking at the existing literature, there are several empirical and theoretical studies on the environment-growth nexus that focused on both developing and developed countries (e.g. [2]; [3]; [4]; [5]; [6]; [7]; [8]; [9]; [10]; [11]; [12]), these studies have offered plausible results and explanations for this nexus. Ironically, they might have suffered from the problem of omitted variables. Secondly, there is still lack of specific study for Nigeria that has employed modern time series econometrics of cointegration and causality to test the causal relationship between pollutant emissions, energy consumption and economic growth in a more coherent framework.

Therefore, pertinent to this methodological flaw, this study aims at filling this gap by investigating the causal relationship between pollutant emissions, energy consumption and economic growth in a multivariate modeling framework while including an indicator for dirty and clean energy sources. This is to show how environmental degradation and other crucial variables affect growth process in Nigeria. From an econometric argument, we include these variables because they are relevant and their exclusion may not only bias the estimates, but also make them inconsistent [13]. Furthermore, since a multivariate modeling framework gives more information than a bivariate framework, the causal inference drawn may be relatively more reliable [14].

The Granger causality test examines the causal relationship between pollutant emissions; energy consumption and economic growth within a multivariate Johansen's cointegration and error-correction framework. In addition to the analysis of Granger causality, this study also considers the individual and block exogeneity of the explanatory variables. This will enhance the robustness of the results.

The remainder of this paper is organised as follows. The next section briefly presents some stylized facts on energy consumption demand and economic growth in Nigeria. In Section three, we give an overview of the literature on environment-energy-growth nexus. Section four is concerned with methodology and the empirical model. Section 5 gives the empirical analysis and results; and section 6 is the conclusion with some policy recommendations.

II. Some Stylized Facts On Energy Consumption Demand And Economic Growth In Nigeria

The Nigerian economy has experienced phenomenal growth over the last one decade with the growth rate averaging about 6 percent in the last few years. Being the most populous nation in Africa with an estimated population of over 160 million, this rapid growth has enlisted this country as the fastest growing economy among developing nations. However, with this strong economic growth, Nigeria demand for energy is increasing just as pollutant emissions (Fig. 1), the diagram shows how the fluctuating nature of energy use, CO_2 emissions and GDP growth correspond to each other overtime. This is because an attempt to achieve higher growth rate and development is usually at the expense of the environment.

According to [11], Nigeria`s GDP per capita growth rate in 2011 was 249.52 percent higher than 1980 value. Although in 2011 the $C0_2$ emission per capita experienced a decline with a growth rate of -50.42 percent of 1980 value, this was not enough to reduce the level of carbon intensity. The country`s carbon intensity experienced a marginal increase of about 12.11 percent of 1980. This is not surprising, given that manufacturing share of the country`s GDP was significantly higher than other sectors`, with services sector which is expected to be environmental-friendly accounting for only 26.6 percent of the GDP in 2010 fiscal year (Table I).

Then, it is also of note that the magnitude of emission of carbons in the country`s atmosphere varied among the sectors and type of energy used. For instance in 2009, as explained by [15] total CO_2 emissions from combustion fuels stood at 41.2 percent while electricity and heat generated 8.2 percent. The manufacturing and construction sectors emitted 3.1 percent while the energy industry stood at 4.5 percent. While, the transport sector was the highest emitter of CO_2 with almost 24 percent with the road sector component dominating. Other sectors cumulating emission stood at 2 percent.

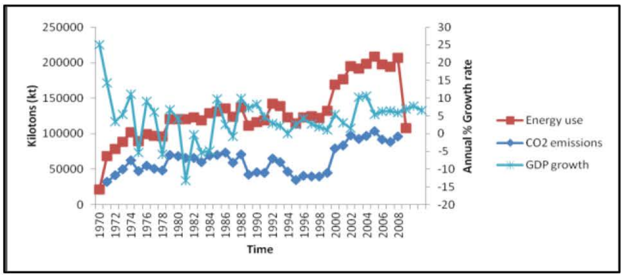

Fig. 1. Trends of Energy Consumption, CO_2 Emission and Growth [15]

TABLE I: Structure of Outputs, GDP Per-Capital and Rate of CO_2 Emission For Selected Countries in West Africa (2009-2010)

Country	GDP Per Capita (US $)	Agric% of GDP*	Industry % GDP*	Manuf.%of GDP*	Services % Of GDP*	$C0_2$ Emission Growth Rate
Nigeria	5.05	32.7	40.7	2.6	26.6	5.55
Ivory Coast	0.37	22.9	27.4	19.2	49.7	2.5
Ghana	5.47	30.2	18.6	6.5	51.1	18.98
Senegal	1.24	16.7	22.1	12.8	61.1	-1.54
Liberia	6.04	61.3	16.8	12.7	21.9	-5.59
Burkina Faso	4.86	33.3	22.4	13.6	44.4	-1.49
Benin	-0.35	32.2	13.4	7.5	54.4	8.92
Togo	1.33	43.5	23.9	10.1	43.5	3.27
average	4.33	33.6	22.9	8.39	43.4	7.29

III. An Overview of The Literature on Environment-Energy-Growth Nexus

The seminal work of [16] presented the premier study on the causal relationship between economic growth and energy consumption, thereafter, several studies have attempted to investigate the causal link in the recent time (see, [17]; [5]; [18]; [19]; [8]; and [11]). Even though this link has been extensively studied in Nigeria, most of these studies mainly focus on testing the validity of the Environmental Kuznets Curve (EKC) (e.g. [20]; [21], [22]; and [23]), and do not consider investigating the causal link of environment-energy-growth nexus in the same framework. However, since fossil-fuel energy use is the main source of global warming, incorporating energy consumption and other growth relevant factors such as human capital and institution in the growth framework can enhance the better understanding of the issues surrounding the effect of global warming.

In view of this, recent studies that attempted to investigate the causal relationship between pollutant emissions, energy consumption and economic growth seems to be inconsistent concerning the direction of causality. For instance, [17] in the U.S.A., found that income does not Granger cause carbon emissions in the short-run but that there is a long-run causal link between energy use and carbon emissions. [24], while using panel cointegration and panel causality tests in investigating some group of countries in South America, discovered that energy use had a positive and a statistically significant impact on emissions while, energy consumption and economic growth cause emissions in the short-run, but in the long-run , there was evidence of a feedback between energy consumption and emissions, and no feedback between real output and pollutant emissions.

For a group of Commonwealth of Independent States, [25], found that both energy consumption and economic growth cause carbon dioxide emissions in the short-run, but there appears to be bidirectional causality between energy consumption and carbon dioxide emissions in the long run. For West African countries, [11], using a Fixed Effects Panel Regression Model examined the relationship between $C0_2$ emission and economic growth found that in the long run, there is an N-Shape relationship between income and $C0_2$ emissions and that the EKC hypothesis is not supported for West Africa. In the case of Nigeria, [15], while relying on Zivot-Andrews unit root test and Gregory-Hansen cointegration test, established that due to structural shifts, there is no causal link between $C0_2$ emission and energy consumption to economic growth.

In China, [26] found that more energy use, higher income and greater trade openness tend to cause more CO_2 emissions. But in a multivariate causality study for China, [27] found a unidirectional Granger Causality running from GDP to energy consumption to carbon emissions in the long-run but neither carbon emissions nor energy consumption leads to economic growth

The above conflicting evidence and results have major implications for reducing CO_2 emissions and economic growth. In a case of unidirectional Granger causality, which runs from CO_2 emissions to economic growth, where rise/fall in CO_2 emissions leads to rise/fall in economic growth, then an energy strategy that encourages reduction of CO_2 emissions could lead to an ultimate decrease in economic growth. By implication, economic growth could be sacrificed in order to reduce CO_2 emissions. Likewise, if causality runs from economic growth to CO_2 emissions, where rise/fall in economic growth cause rise/fall in CO_2 emissions, then, an energy policy that reduces CO_2 emissions may have no negative effect on economic growth. This implies that, it may be possible to reduce CO_2 emissions without necessarily harming economic growth. But in a case of no causality running in any direction, then, the neutrality hypothesis is not rejected, and reducing CO_2 emissions may not affect economic growth. In contrast, if there is a bi-directional causality running between the two, and economic growth leads to more CO_2 emissions, then this may increase the environmental degradation.

Methodology

1. *The Model*

The study adopts the standard EKC specification developed by [28] in investigating the environmental pollution impact of North America Free Trade Agreement (NAFTA). The model has been extended and applied to developing Africa economies by extant studies such as [29]; [30]; and [31] to ascertain the effect of income on environmental quality. An expended EKC model for the study is presented thus:

$$LCO2_t = \beta_0 + \beta_1 LY_t + \beta_2 (LY)_t^2 + \beta_3 LFC_t + \beta_4 LHC_t + \beta_5 LPC_t + \beta_6 IST_t + \mu_t$$

The description of the variables is as follow:

$LCO2_t$: CO_2 emissions (kiloton)

LY_t: GDP per capita (2005 constant US$)

LFC_t: Fossil fuel energy consumption

LHC_t: Human Capital (proxied by total school enrolment)

LPC_t: Electric power consumption (kWh)

IST_t: Institutions (average of four indicators provided by WGI- Government effectiveness, Regulatory quality, Rule of law and Control of corruption)

2. *Data Source*

The study adopted an annual time series data for the period 1970 to 2013 for Nigeria. The data for GDP per capita, CO_2 emissions, electric power consumption, fossil fuel consumption, and school enrolment (proxy for human capital) were obtained from the [32] of the World

Bank while the data for institutions were sourced from the [33] of the World Bank.

3. *Estimation Procedure*

The analyses in this paper are carried out in three phases. The estimation process began by conducting the unit root test using Augmented Dickey-Fuller (ADF) and Philip Perron (PP) tests. This becomes expedient to avoid spurious regression. Secondly, we estimated the Johansen maximum likelihood cointegration test and the vector error correction model to obtain the long run estimates and ascertain the long-run sustainability of the model respectively. Finally, we conducted the block Wald exogeneity granger causality test in order to ascertain the direction of causal relationship among the variables in the model.

4. *Discussion of Results*

The estimation process began by examining the time series properties of the variables in the model. For the purpose of ensuring a robust analysis, the Augmented Dickey-Fuller (ADF) and the Philip Perron (PP) tests were employed. According to the tests, the series all became stationary at first difference, it implies that we failed to reject the null hypothesis of no unit root at I (0); hence, the series were integrated at order I (1)

Having satisfied the sufficient condition of integration at order I (1) for the series, the study proceeds to estimate the Johansen cointegration tests. The Johansen likelihood test is preferred to the Engle-Granger two step procedure as the former enable a simple straightforward analysis and capable of generating the long-run coefficient estimates. Two prominent tests are conducted in the Johansen cointegration analysis – the trace and the maximum eigen value tests. The trace and the maximum eign value tests indicate one and two number of cointegration ranks respectively. The cointegrating vector is ascertained at points where the test statistics is less than the critical values.

As aforementioned, the Johansen technique presents the long-run estimates. It is worthy to note that the approach is a multivariate analysis in which all variables are regarded as endogenous, and in order to ascertain the relationship among the variables, we simply normalised the explanatory variables with the coefficient of the dependent variable. The normalised long run model shows that at GDP per capita and the squared of GDP per capita varies inversely and directly with CO_2 emissions respectively, hereby refuting the EKC hypothesis. Consequently, fossil fuel influences CO_2 significantly and positively. The result reveals that a percent change in fossil fuel consumption leads to about twenty percent change in atmospheric carbon dioxide concentration. To put succinctly, fossil fuel exerts a fairly large positive elastic variation on carbon emissions. The evidence portrays the present reality in Nigeria, as inadequate supply of cleaner energy sources has limited the substitutability of fossil fuel. Fossil fuel is consumed practically in all social and economic facets of human activities, ranging from automobiles, household and business power generating purposes.

On the other hand, electric power consumption (a cleaner energy source) varies significantly and negatively with CO_2 emissions. This implies that substituting cleaner non-fossil energy for fossil fuel significantly improves environmental quality. Also, the indicator of human capital and institutions does not influence CO_2 significantly. This might not be unconnected with the weak quality of regulatory enforcement in Nigeria, the bureaucratic inefficiencies in the electricity sectors had left everyone to the use of dirty energy sources.

Having established the existence of cointegration, the study proceeds to estimate the vector error correction model (VECM). The model incorporates the error adjustment mechanism into the system of equations. This ensures that immediate errors in the model are corrected in the successive periods. In order to attain a meaningful error correction, the ECM is expected to be negative, its absolute value must lie between 0 and 1 and the t-statistic must be significant. The estimated result shows an error correction coefficient of -0.0158, implying that about 2 percent of short run errors are corrected as the model attains its long run equilibrium. The low absolute value of the ECM coefficient indicates that errors (deviations) are weakly restored in the model. Table IV presents the result of the block exogeneity Granger causality test. The test result shows evidence supporting a unidirectional causality from fossil fuel to CO_2 emissions and GDP per capita. That is, changes in fossil fuel consumption Granger causes a change in the level CO_2 emissions and GDP per capita. This implies that dirty growth accounts for significant proportion of Nigeria growth experience. On the other hand, a unidirectional causality runs from electric power consumption to GDP per capita but the study found no evidence of causality between electric power consumption and CO_2 emissions. These evidences suggest that cleaner energy sources (electricity) do not contribute to environmental degradation and thus suitable towards attaining a sustainable environment. Finally, the Wald causality test provides insight on the exogeneity status of explanatory variables, the rejection of the null hypothesis indicates that fossil fuel, electric power consumption and education are truly exogenous to the model.

CONCLUSION AND RECOMMENDATION

The study investigates the direction of causal relationship among pollutant emissions, energy consumption and economic growth in Nigeria using annual time series data for the period 1970-2013. The study adopted the maximum likelihood Johansen cointegration technique;

TABLE II: UNIT ROOT TEST

	Augmented Dickey-Fuller		Philip Perron	
Variables	*With a time trend*	*Without a time trend*	*With a time trend*	*Without a time trend*
Ly	-0.0711 (3)	0.1242 (3)	-0.2987 (3)	-0.3838 (3)
Lco2	-2.4148 (3)	-2.332 (3)	-2.4086 (3)	-2.3107 (3)
Lpc	-2.8425 (3)	-1.0369 (3)	-2.9050 (3)	-0.6833 (3)
Lfc	-2.2459 (3)	-3.1663 (3)	-2.2368 (3)	-3.1615 (3)
Lhc	-2.5282 (3)	-2.2906 (3)	-1.8825 (3)	-2.0872 (3)
List	-2.1434 (3)	-0.5734 (3)	-6.2700 (3)	-2.3486 (3)
Δ *ly*	-6.4045 (3)***	-5.7812 (3)***	-6.4020 (3)***	-5.9044 (3)***
Δ *Lco2*	-6.8411 (3)***	-6.9034 (3)***	-6.8188 (3)***	-6.8791 (3)***
Δ *lpc*	-8.5202 (3)***	-8.6315 (3)***	-8.7256 (3)***	-8.8516 (3)***
Δ *lfc*	-5.8626 (3)***	-5.3733 (3)***	-5.8503 (3)***	-5.3605 (3)***
Δ *lhc*	-3.3731 (3)***	-3.2839 (3)***	-3.4639 (3)***	-3.3668 (3)***
Δ *ist*	-20.4210 (3)***	-20.5864 (3)***	-26.2548 (3)***	-23.6888 (3)***

Source: Computed using e-views 7.0

Lag lengths (in parenthesis) are determined by AIC

TABLE III: MAXIMUM LIKELIHOOD COINTEGRATION TESTS

Cointegration Rank	*Trace test*			*Maximum Eigen test*		
	Statistics	*Critical value*	*Prob**		*Critical Value*	*Prob**
None*	175.6081	139.2753	0.0001	56.9581	49.5868	0.0073
At most 1	118.6500	107.3466	0.0073	40.1915	43.4198	0.1078
At most 2	78.4585	79.3415	0.0581	23.7425	37.1636	0.6811
At most 3	54.7160	55.2458	0.0556	19.1633	30.8151	0.6178
At most 4	35.5527	35.0109	0.0437	17.0058	24.2520	0.3363
At most 5	18.5469	18.3977	0.0477	10.9629	17.1477	0.3146
At most 6	7.5841	3.8415	0.0059	7.5841	3.8415	0.0059

Normalized cointegration equation

$$LCO2 + 161.388(0.74)LY - 12.460(-0.74)LY^2 - 20.181(-6.12)LFC + 0.297(0.09)LHC + 23.646(7.98)LEP - 2.636(-1.47)\ IST + 4.712TREND$$

Error correction coefficients

Variable	Δ *(LCO2)*	Δ *(LY)*	Δ (LY^2)	Δ *(LFC)*	Δ *(LHC)*	Δ *(LPC)*	Δ *(IST)*
ECM(-1)	-0.0158	-0.0091	-0.1238	0.0073	0.0069	0.0057	-0.0194
*t-stat**	-1.6155	-2.2305	-2.3363	1.3448	2.0827	0.5918	-0.9861

Source: Computed using e-views 7.0

95% critical value; The lag structure of VAR is determined by AIC; T-values are given in parentheses.

TABLE IV: BLOCK EXOGENEITY GRANGER CAUSALITY TEST

Dependent variables	F- statistics							T-statistics
	Short-run							Long-run
	Δ *(LCO2)*	Δ *(LY)*	Δ (LY^2)	Δ *(LFC)*	Δ *(LHC)*	Δ *(LPC)*	Δ *(IST)*	ECT_{t-1}
Δ *(LCO2)*	0.9821	0.8913	0.2821	0.0515*	0.0430*	0.2818	0.2882	-1.6155*
Δ *(LY)*	0.1911	0.8621	0.3881	0.0918*	0.9911	0.0432*	0.8139	-2.2305*
Δ (LY^2)	0.2917	0.3872	0.8768	0.0895*	0.9281	0.1821	0.3819	-2.3363*
Δ *(LFC)*	0.8971	0.1823	0.1277	0.9821	0.6517	0.1291	0.9821	1.3448
Δ *(LHC)*	0.8392	0.8910	0.8720	0.7821	0.7810	0.7819	0.3667	2.0827*
Δ *(LEP)*	0.1871	0.5711	0.7631	0.2863	0.9721	0.7829	0.3765	0.5918
Δ *(IST)*	0.2876	0.6891	0.3681	0.7681	0.1821	0.8611	0.3767	-0.9861

Source: Computed using e-views 7.0

the normalized long run estimates show that fossil fuel consumption enhances the level of environmental degradation in Nigeria by increasing more than proportionately the concentration of CO_2 emissions. Conversely, electric power consumption varies inversely with carbon emissions, implying that as adoption of cleaner energy source (electricity) increases, the atmospheric concentration of carbon emissions dwindle. The result from the Wald exogeneity causality test indicate an evidence supporting a unidirectional causality running from fossil fuel to CO_2 emissions, GDP per capita and the squared of GDP per capita. Also a unidirectional causal relation exists from electric power consumption and indicator of human capital GDP per capita and CO_2 emissions, respectively. The foregoing evidence reveals that, though, the consumption of dirty fuel sources enhance per capita income but its increasing use jeopardizes the sustainable environment agenda by increasing the accumulation of CO_2 concentration. Alternatively, electric power consumption granger causes GDP per capita but has no causal link with CO_2, the finding from the Johansen long run estimates corroborates this fact which implies that cleaner energy sources is capable of charting an appropriate platform towards attaining a sustainable environment and economic development.

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