

ECONOMIC GROWTH AND ITS ENVIRONMENTAL COST: ENERGY CONSUMPTION AND CARBON EMISSIONS IN NIGERIA

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Abstract

This study examines the nexuses amongst Carbon Emission, energy Consumption and economic growth in Nigeria utilizing the ARDL approach to cointegration. Time series data was employed from 1981 – 2023. To achieve the main objective of the study an econometric model expressing the relationship amongst Gross Domestic Product, Carbon Emissions, energy consumption and electricity consumption was used. The unit root test was carried out to establish the stationarity of the variables, the output of the result indicated that the time series variables were found to be stationary after the first difference and hence they are series of order (1). The result reveals that the intercept and the coefficient of Carbon emission are negative. This means that one percent change in Carbon emission will lead to a decrease in the percentage of GDP. Energy consumption is significant while electricity consumption is insignificant. This is not surprising given the epileptic power supply in Nigeria. The policy implication deduced from the study is that government should improve on electricity supply to boost economic activities in the country.

Keywords: Carbon Emission, Energy Consumption and Economic Growth

1.0 Introduction

This research seeks to evaluate the inter-relationships amongst energy consumption, carbon emissions and economic growth in Nigeria. The nexus amongst these variables have received massive attention by researchers, governments and professionals in recent years. This interest has been propelled by the consistent rise in the prevalence of global warming and climate change. The role of energy consumption in the growth of both advanced and developing countries cannot be over-emphasized. Most growth models include energy consumption as a major determinant affecting growth, explicitly or implicitly as an accompanying factor to labour and capital in the production function (Dantama, et al., 2012). The alarming increase in the levels of carbon dioxide (CO₂) and other greenhouse gasses into the environment constitutes the world's greatest environmental challenge. CO₂ emissions play a dominant role in increasing greenhouse effects amongst other greenhouse gasses and this effect is well over 60% (Alkhatlan & Javid, 2013). The production of energy and its consumption patterns, energy intensity, price and supply of energy are strongly related to CO₂ emissions growth trends. Energy consumption is a panacea for industrial development and economic growth; invariably, it is strongly advocated that a country with high levels of energy consumption is likely to have a high level of living standards. On the other hand, high energy consumption has a positive correlation with carbon emissions which affects the environment negatively. Consequently, several intensive studies have been carried on the effects of global warming and climate change on the economy by academics and practitioners.

In empirical literature, there exist two theoretical points of view on the link between energy consumption and economic growth; the neo-classical view postulating neutral relationship between economic growth and energy

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consumption which advocates the pursuance of energy conservation policy for reduction in CO₂ emissions without affecting the rate of growth. This theory is known as the “neutral hypothesis”. (Halicioglu, 2009); (Alkathlan & Javid, 2013) and (Mehmet & Etem, 2015) in their works did find proof for this theory of no causal relationship between energy consumption and economic growth for Turkey, Saudi Arabia and OECD countries respectively. On the other hand, the second theory advocates that energy consumption and economic growth are highly associated due to the fact that energy as any other factor of production may be the limiting factor to economic growth. Many authors like (Wolde-Rufael, 2005) for 19 African countries; (Mahadevan & Asafu-Adjaye, 2007) for Philippine and Thailand; (Lee & Chang, 2008) for 17 Asian countries found evidence that energy is a strong determinant of economic growth. In this postulation, reduction in energy consumption tends to reduce output growth and thus energy conservation policies may inhibit the growth of the economy.

The other strand of this research work is related to the relationship between economic growth and environmental pollution. Scholars have been trying to validate this relationship with the theoretical framework of the Environmental Kuznets Curve (EKC) hypothesis. According to the EKC hypothesis, there exists an inverse U-shaped relationship between economic growth and environmental pollution, portraying increase in levels of environmental pollution as country develops Vis a Vis a reduction as increasing incomes go beyond the point of inflection on the curve. The main thesis of the Kuznets curve hypothesis is that high levels of income per capita, leads to environmental improvements. Most recently, a wide range of research has focussed on combining the nexuses amongst energy consumption, economic growth and carbon emissions. This approach facilitates the assessment of the inter-relationships amongst economic growth, energy consumption and environmental pollution simultaneously (Alam, et al., 2011)

This research work adapts this concept but stretches beyond the above mentioned multivariate approach by disaggregating the energy consumption component into electricity, gas and oil and regressing each component against carbon emission separately. This will lead to finding out the impact of each component on carbon emissions and limit the problem of omitted variables in the model that will be employed. It will also resolve the issue of collinearity in the econometric estimation. The study will, therefore, examine the long run and the short run relationships between carbon emissions and economic growth in Nigeria. The theoretical underpinning is the Environmental Kuznets Curve (EKC) hypothesis. Other strand of the study will be to analyse the impact of energy consumption on carbon emissions. To add more strings to empirical literature and knowledge, energy consumption has been split into three components (oil, natural gas and electricity) and then their individual impacts on carbon emissions will be assessed in the study.

Steady intensification of human enterprise tends to keep carbon emissions on the increase. This involves fossil fuel burning, energy consumption (oil gas and electricity), the use of coal, bush burning etc. the attainments of high growth targets has propelled economies to involve in industrial revolution that inevitably requires large magnitude of energy consumption. Intuitively, carbon dioxide is the largest component of greenhouse emissions (Kaygusuz, 2009). The United Nations has made concerted efforts to reduce the impact of environmental depletion and climate change through signing treaties by various governments, for instance, the Kyoto Protocol

(Halicioglu, 2009). The protocol was originally adapted on December 11, 1997, Kyoto, Japan, and was implemented officially on 16th February, 2005. As at September 2001, 191 countries had signed and ratified the protocol. This protocol is weighed as an essential reinforcement on the way to fighting global emissions reduction regime that will balance greenhouse gasses and provide the necessary framework for any future international treaties on climate change. Nigeria as a signatory to this treaty ratified it on December 10th, 2004 as the 130th member (Oppenheimer, 2005), accordingly, boosting continual advancement and fighting climate change have emerged as a fundamental facet of national development strategy and planning in many nations of the globe including Nigeria.

The Nigerian economy is an oil producing economy and constitute energy demanding precinct such as manufacturing, transportation and infrastructure, electricity generation, agriculture and land use etc. Consequently, overall energy dispersion is rising speedily in the country in spite of efforts and precepts maintained. Moreover, Nigeria is Africa's largest supplier of energy. It is the region's most fertile oil producing country which in conjunction with Libya amount to two-third of Africa's crude oil reserves. Nigeria is next to Algeria in natural gas (Oyedepo, 2012). About 82% of Nigeria's utilized energy, from the yearly data is at 94,682kteo, emanates from biofuels and waste. Nearly 11% originates from traditional energy sources, mostly imported refined oil products, the proportion of electricity in final energy consumption is almost at less than 2% (NIGERIAN ENERGY SUPPORT PROGRAMME, 2014).

The preference of Nigeria for this research work is inspired by the evidence that Nigeria has encountered an acute upsurge CO₂ emission in current times resulting from a hike in economic activities and industrial growth. Climate vulnerability in Nigeria differ in proportion, asperity and extremity. A study undertaken by Department for International Development (DFID), (2009), is of the view that if no adjustment framework is designed, about 2-11% of Nigeria's GDP could be forfeited by 2020. In the same vain, the Post Disaster Need Assessment (PDNA) report culminating from the 2012 downpour affirmed that the overall devastation occasioned by the flood added up to \$16.9billion, depicting 1.4% of real GDP growth in that year. Consequently, climate adjustments present a serious risk to the actualization of developmental goals, remarkably those connected to eradicating poverty and hunger, and stimulating environmental friendliness (Oppenheimer, 2005). However, Nigeria's growth rate has stood around 6% in the last ten years. In spite of this spectacular pace, electricity generation which is supposed to be the main hub of energy source, thereby stimulating economic development is very erratic and unstable. Apparently, this has propelled a shift from the utilization of electricity to other sources of power that evolve around the burning of conventional fuels. Therefore, leading to an increase in carbon emissions in the Nigerian economy (Chindo, et al., 2015).

It is against this backdrop that this study seeks to establish the nexus amongst carbon emissions, energy consumption and economic growth in Nigeria using the ARDL approach to cointegration To actualise this main objective the following sub objectives will be examined: To ascertain the patterns of short-run and long-run relationship between carbon emission and gross domestic product {investigating the environmental Kuznets curve (EKC)} in Nigeria; To analyse the overall impact of energy consumption on carbon emissions and decompose

energy consumption into electricity, oil and natural gas consumption, and investigate their effects on the total carbon emissions in Nigeria. This part of the objective will help ascertain the contributions of each component of energy consumption on the overall carbon emissions in Nigeria.

Adopting time series data within the period of 1981 to 2023 and instrumenting with the Autoregressive Distributive Lag Model (ARDL) approach to cointegration, the study revealed there was no significant relationship between carbon emissions and gross domestic product in Nigeria both in the short run and long run. However, total energy consumption was found to be significant in the study. For the decomposed models where the impact of oil, natural gas and electricity consumption on carbon emissions were examined, it was established that the three components of energy consumption were statistically significant both in the long run and short run except for electricity which was not significant in the long run. It was also affirmed by the study that electricity is less polluting than oil and natural gas consumption. Therefore, for Nigeria to attain its aspiration of an ecologically-safe surrounding and at the same time achieving a viable economic growth trend, the study advocates for the generation of more electricity.

2.0 Literature review

2.1 Carbon emissions and economic growth

This string of literature is associated with verifying the existence of the relationship carbon emissions and economic growth. The nexus between environmental pollutants and economic growth is authenticated by the Environmental Kuznets Curve (EKC), which speculates that at the nascent levels of economic growth, environmental depletion and pollution is on the high side, but after some attainment of income per capita, which will alternate in different countries for diverse index, the direction switches, so that soaring levels of per capita income drives the economy to environmental amelioration (Stern, 2004).

A couple of studies by (Stern, 2004); (Choi, et al., 2010); (Dinda & Coondoo, 2006); (Bradford, et al., 2001); (Managi & Jena, 2008) and (Boopen & Vinesh, 2011) investigated the subsistence of the environmental Kuznets curve (EKC) for carbon emissions environmental depletion during early stages of income growth. Employing time series analysis and different indicators for environmental pollution, the studies affirmed the position of the EKC on environmental depletion during the early stages of income growth. The studies further revealed that developing nations are devoting efforts to reducing environmental degradation periodically by adapting advanced nations specifications within brief time periods and occasionally achieving more than some developed countries. However, the studies above conclude that the EKC model is unique to every economy, therefore, varies amongst countries and amongst different indicators of environmental specifications. Be that as it may, most of the studies applied the bivariate (where carbon emissions is regressed on Gross Domestic Product and its squared) model to establish the relationship, which is often bedevilled by the problem of multicollinearity and omitted variable bias. On the other hand, (Nasir & Rehman, 2011); (Annicchiarico, et al., 2014); (Moomaw & Unruh, 1997); (Dijkgraaf & Vollebergh, 2005); (He & Richard, 2010); (Jalil & Mahmud, 2009.); (Aslanidis, 2009.); (Beck & Joshi, 2015.); (Selden & Song, 1994); and (Harbaugh, et al., 2002) in their various studies in examining the empirical evidence of the environmental Kuznets curve, employing different methodologies ranging from the Autoregressive

distributive lag (ARDL) model approach to cointegration, Panel data approach to cointegration and the vector error correction model seems to agree that there is a little support for an inverted “U” shaped relationship several important air pollutants and gross domestic product. The studies however, concluded that the EKC results have a very flimsy statistical foundation and the current formation of decomposition and efficient frontier models, can assist unwind the actual nexus between development and environmental depletion and could lead to the extinction of the classic EKC.

Though these studies have tried to establish empirical evidences of the EKC, a number of number of shortcomings in the studies ranging from theoretical, econometric and other evidences have been largely observed. The main theoretical criticism is noted by (Arrow, et al., 1995) and others, they argue that the EKC as presented lacks feedback from pollution to economic production as GDP is believed to be an exogenous parameter. The postulation is that emissions does not affect economic growth enough to hinder the growth mechanism but if the level of economic growth are not sustainable, pursuing speedy economic growth in the nascent stage of development when environmental depletion is on the increase may manifest unproductive results. The econometric criticisms of the EKC studies are flocked around heteroskedasticity, the authenticity of the stationarity tests, omission of variables bias and cointegration problems.

2.2 Energy Consumption and Economic Growth

The nexus between energy consumption and economic growth has been investigated widely in recent years, notwithstanding, the affirmation of this relationship still remains contestable. The analysis in literature has no uniform inference as a result of differences in countries, periods covered in the studies, analytical framework and methodology. Empirical literature on energy consumption and economic growth tries to establish the causality between the two variables. (Ozturk, et al., 2010); (Huang, et al., 2008); (chontanawat, et al., 2008) and (Soytas & Sari, 2003) employing time series data and panel data analysis, in their studies segregated the countries under study into major groups; low income, lower income, middle income, upper middle income and high income group countries. Their findings revealed that energy consumption and GDP are cointegrated for all groups; the panel causality test established that they were long run Granger causality running from GDP to energy consumption and economic growth for middle income countries; and finally, no strong correlation was instituted between energy consumption and economic growth for all categories classified in their studies. However, in most of these studies, only GDP per capita and energy consumption was considered in their estimates. The performance of a country’s GDP is also influenced by many economic and demographic factors, which were not included in their studies, these variables could include human capital, foreign direct investment, population density etc.

(Paul & Bhattacharya, 2004); (Asafu-Adjaye, 2000); (Wolde-Rufael, 2005); (Mehrara, 2007); (Lee & Chang, 2008); (Belke, et al., 2011); (Apergis & Payne, 2009); (Tsani, 2010); (Lise & Van Montfort, 2005) and (Kaygusuz, 2009) in various detailed studies on the relationship between energy consumption and economic growth, found either a unidirectional or bidirectional causality between energy consumption and economic growth. Regrettably, a large number of these studies applied the use of time series data of individual countries and outcome of these studies are mostly flawed by limited data span, which reduces the authenticity of the unit

root test and cointegration tests. More so, the studies did not take into cognisance the possibility of endogeneity in the parameters. Contemporary studies have come up with new methodologies to address these problems by applying the dynamic panel date approach. On the contrary, studies by (Cheng, 1995); (Masih & Masih, 1996); (Akinlo, 2008); (Narayan & Smyth, 2008) and (Chiou-Wei, et al., 2008) examined causality between energy consumption and economic growth employing both bivariate and multivariate models by utilizing the currently advanced methodologies, these group of studies found no causal relationship between energy consumption and economic growth. Notwithstanding, the causality relationship between energy consumption and economic growth is erratic. Macroeconomic trends are normally impacted by exogenous shocks (Lee, 2005). Time series data are subject to structural breaks, such breaks if not appropriately identified and taken into consideration while estimating causality between energy consumption and economic growth, will lead to misleading inference about the direction, strength and stability of this relationship. To avoid this limitation, latest studies have evolved cointegration test that can be used for to integrate structural breaks.

2.3 Carbon emissions, energy consumption and economic growth

The consolidation of these two propositions discussed above has emanated in recent studies and empirical literature, which expedites the exploration of active nexus amongst carbon emissions, energy consumption and economic growth. The review of this strand of literature will be done in two folds; the studies in single or specific countries and the studies for group of countries or regional studies.

On the relationship amongst carbon emissions, energy consumption and economic growth for specific country studies, (Pao & Tsai, 2011); (Alam, et al., 2012); (Alkhathlan & Javid, 2013); (Ang, 2007) (Wang, et al., 2011); (Halicioglu, 2009); (Chebbi & Boujelbene, 2008); (Magazzino, 2014) and (Bozkurt & Akan, 2014) explored the nexuses using mainly the time series analysis, focussing on the Error Correction Model (ECM) and the cointegration approaches, the studies, however, failed to achieved homogeneous results. Some studies found evidence of a causal link amongst carbon emissions, energy use and economic growth while very few did not. Unfortunately, most of the studies suffered from the problems of misspecification of the model, omission of variables and limited data sample.

In the second fold of the literature, countries were grouped either by regions or economic affiliations, to examine the relationship amongst carbon emissions, energy consumption and economic growth. (Apergis & Payne, 2009), for six Central American countries, employed the vector error correction model and found a bidirectional causality from energy use to carbon emissions (Lean & Smyth, 2010) investigated five Asian countries, and the results pointed to a unidirectional link running from energy consumption to economic growth. (Holtz-Eakin & Selden, 1995), for 130 countries with High Marginal Propensity to Emit (MPE) established a bidirectional causality amongst the variables. (Omri, 2013) explored the relationship in Middle East and North African countries (MENA) and established a bidirectional causal link between energy use and growth but the results showed a unidirectional link from energy use to carbon emissions (Richmond & Kaufmann, 2006); (Arouri, et al., 2012) and (Mehmet & Etem, 2015) examined the link amongst carbon emissions, energy consumption and economic growth for 36 countries (OECD & NON OECD), 12 Middle East and North African countries (MENA), and

selected OECD countries respectively, all the studies established cointegration relationship amongst energy use, economic growth and carbon emissions.

2.4 Carbon emissions, energy consumption and economic growth in Nigeria The interaction amongst carbon emissions, energy consumption and economic growth has not really been studied extensively over the past decades for the Nigerian economy. However, a couple of scholars have been able to indicate interest in the subject in recent years. (Gbadebo & Okonkwo, 2009), examined the interaction prevailing between energy consumption and economic growth in Nigeria using annual data from 1970 to 2005, employing the use of Autoregressive Distributive Lag Model (ARDL) method to cointegration, the study found a unidirectional relationship between total energy consumption and economic growth. The cointegration analysis pinpoints a long run interaction between energy consumption and economic growth. In another study undertaken by (Mustapha & Fagge, 2014), to review the causal relationship between energy consumption and economic growth in Nigeria employing data from 1980 to 2011, utilizing the Granger causality test, the study found that there was no causality flowing from energy to output.

(Nnaji, et al., 2013), investigated the relationship amongst the three variables but disaggregated energy consumption into electricity supply and fossil fuel consumption. The period under study was 1971 to 2011, using a multivariate framework, the findings revealed that economic growth is linked with higher CO₂ emissions while a direct relationship exist between power supply and CO₂ emissions unveiling the epileptic nature of electricity supply in Nigeria. Also, (Alege, et al., 2015) employed annual time series data from 1970 to 2013, adopting the maximum likelihood Johansons cointegration method and found that in the long run fossil fuel consumption enhances the level of environmental depletion in Nigeria but the study could not affirm any causal link between electricity and CO₂ emissions.

(Chindo, et al., 2015), examined the interaction amongst energy consumption, carbon emissions, and economic growth in Nigeria making use of the Autoregressive Distributive Lag Model (ARDL) approach to cointegration. The study found the existence of a long run relationship amongst energy use, CO₂ emissions and output; in the long run and short run, CO₂ emissions have been revealed to have significant impact on GDP; and finally, energy consumption shows significant negative impact on GDP in the short run. But (Gbadebo & Okonkwo, 2009), limited their study to only the interaction between energy consumption and output using the cointegration method from 1970 to 2005 and concluded energy consumption is a strong determinant of economic growth.

(Saibu, 2013), examined causal relationship on oil production and carbon emissions with specific interest on gas flaring and output in Nigeria between 1970 and 2011, the analysis proved that output growth rate, distortion in crude oil yield, gas flaring emissions are prominent determinants of national income in Nigeria. The study drew a conclusion that there was a causative interaction between gas flaring and output. (Dantama, et al., 2012), on the interaction between energy use and output in Nigeria, within the period of 1980 to 2010 and employing the Granger causality test, affirmed that unidirectional causation flows from energy use to output. Also, (Ogundipe & Apata, 2013), tested only electricity usage and output in Nigeria using the Vector Error Correction Model

(VECM) and found that an exclusive causation run between power consumption and output. The study also reveals a two-way causation between power consumption and economic growth.

However, these studies modelled for Nigeria have a lot of limitations, prominent amongst them is the model misspecification problem. Most of the studies specified carbon emissions as a function of Gross domestic product and Gross domestic product squared and/ or cubed in addition to other independent variables. Consequently, the models experienced the issues of multicollinearity and omitted variables bias. This study did not include the squared and cubed parameters of GDP to avert this problem. Also, none of the studies reviewed so far, disaggregated the energy consumption parameter into oil, gas and electricity in one study to examine the impact of each component on carbon emissions in Nigeria. This disaggregation in the current study will also prevent the problem of endogeneity in exploring the nexuses amongst carbon emissions, energy consumption and economic growth in Nigeria.

3.0 Methodology and Data

From past works, it was noted that mainly the Error correction model (ECM), Granger cointegration, Hsiao's Granger and the Autoregressive Distributive Lag model (ARDL) have been widely used in this area. However, out of all these, the Autoregressive Distributive lag model (ARDL) approach to co-integration recently developed by Pesaran et al (2001) to assess the relationship between the relationship between Co2 emissions energy consumption, labour and GDP in case the of Nigeria over the period of 1981-2023 will be employed in this study. The ARDL approach to co-integration has been priority amongst others due to its superiority over other methods of testing co-integration. As stated by Emran et al (2007) and (Manyah and Wolde-Rufael 2010), the Monte Carlo evidence shows that it has several important advantages over the other conventional methods which include correcting the possible endogeneity of explanatory variables, good properties for small sample estimation, does not formally require unit root test as it is not affected by order of integration of the variables and lastly it allows both long run and short run model to be estimated simultaneously.

There are two major questions/ hypothesis this paper seeks to address, to seek if there is a long run or short run impact between GDP and co2, and secondly to ascertain whether energy consumption impacts on GDP in the long run and short run. To effectively address the second question, energy consumption is also captured in electricity consumption so the question of if electricity consumption has an impact on GDP is also reflected in the model. In order to capture the long run and short run impacts of carbon emissions, energy consumption and electricity consumption on Gross Domestic Product (GDP), the model is expressed in form to allow us do the necessary testing of the auto regressive distributed lagged model (ARDL). The economic model is specified below;

$$GDP = f(CO_2, ECON, ELC)$$

To determine the mathematical relationship between Carbon Emissions, Energy consumption and Economic Growth, at this point, ARDL approach to co-integration is estimated on the following error correction regression;

$$\Delta \ln GDP_t = \alpha_0 + \sum_{i=1}^n \lambda_i \Delta \ln GDP_{t-i} + \sum_{i=0}^n \delta_i \Delta \ln CO_2_{t-i} + \sum_{i=0}^n \phi_i \Delta \ln ECON_{t-i} + \sum_{i=0}^n \theta_i \Delta \ln ELC_{t-i} + \Pi_1 \ln Y_{t-1} + \Pi_2 \ln CO_2_{t-1} + \Pi_3 \ln ECON_{t-1} + \Pi_4 \ln ELC_{t-1} + vt$$

Where $\ln GDP_t$ is the natural log of Gross Domestic Product, $\ln CO2_t$ represents the natural log of carbon emissions, $\ln econ_t$ the natural log of energy consumption and $\ln elc_t$ is the natural log of electricity consumption. To estimate the long run relationship, we test the joint significance of the coefficient of lagged variables using F test under the following hypothesis; The null hypothesis of no co-integration is tested against the alternative based on the F statistics value obtained when compared with two sets of critical values tabulated by Narayan and Smith (2005). The two sets of critical values are $I(0)$, the lower critical bound and $I(1)$, the upper critical bound. If the calculated F statistics exceeds the upper bound, co-integration exist, therefore, we do not reject the null. If the calculated F statistics falls below the lower bound, co-integration does not exist, therefore, we reject the null. If the F statistics falls between the lower and the upper bounds, we say it is inconclusive, inference cannot be made unless the order of integration of the variables are known. If we find co-integration, we estimate the following long run model:

$$\ln GDP_t = \alpha_1 + \sum_{i=1}^n x_{1i} \ln GDP_{t-i} + \sum_{i=0}^n \delta_{1i} \ln CO2_{t-i} + \sum_{i=0}^n \phi_{1i} \ln ECON_{t-i} + \sum_{i=0}^n \gamma_{1i} \ln ELC_{t-i} + \alpha v_{1t}$$

Therefore we proceed to estimate the error correction model below:

$$\Delta \ln GDP_t = \alpha_2 + \sum_{i=1}^n x_{2i} \Delta \ln GDP_{t-i} + \sum_{i=0}^n \delta_{2i} \Delta \ln CO2_{t-i} + \sum_{i=0}^n \phi_{2i} \Delta \ln ECON_{t-i} + \sum_{i=0}^n \gamma_{2i} \Delta \ln ELC_{t-i} + \lambda ECT_{t-1} + \varepsilon_{2t}$$

Where λ is the error correction term which shows the speed of adjustment of the variables to equilibrium in the long run annually and ECT_t is defined as $ECT_t = \ln GDP_t - \alpha_1 - \sum x_{1i} \ln GDP_{t-i} - \sum \delta_{1i} \ln CO2_{t-i} - \sum \phi_{1i} \ln ECON_{t-i} - \sum \gamma_{1i} \ln ELC_{t-i}$

The data used for the analysis to establish the relationship amongst energy consumption, carbon emissions and economic growth in Nigeria is taken between 1970 and 2013. The time frame is taken based on the availability of data from sources. The data sourced for the analysis of this study are presented and employed to estimate the multiple regression model specified earlier in this section. To investigate the empirical relationship among carbon emissions, energy consumption and GDP, the model designed for the study is a multiple regression equation. The model predicts the relationship between the dependent variable (GDP) and independent variables (CO2, ECON AND ELC). The study tries to use a dynamic methodology in the form autoregressive distributed lagged model approach to examine the effect of carbon dioxide, energy consumption and electricity consumption on GDP in Nigeria. The model is estimated using data from International Energy Agency (IEA) publications for the period of 43years (1981-2023), this period was chosen because of availability of data.

4.0 Empirical Results and Discussion

A. Unit Root Tests

The first and prime step of the analysis in the nexus between energy consumption, carbon emissions and economic growth requires that all the variables should be integrated of the same order, most preferably, $I(1)$. The ADF unit root test is used to check since it was observed that most of the variables were not stationary at level, the log difference of the variables were then examined and the estimated results of these are reported in Table 1. The

output of the results indicated that the time series variables, change of gross domestic growth rate (Δgdp), change in carbon emission rate (Δco2), change in energy consumption growth rate (Δecon), and change in electricity growth rate (Δelc) were found to be stationary after the first difference and hence they are series of order one $I(1)$.

TABLE 1: ADF Unit Root Test Results

VARIABLES	INTERCEPT	ORDER OF INTEGRATION
Δlngdp	0.0254(-3.6056)	1
Δlnco2	0.2011(-3.6056)	1
Δlnecon	0.0112(-3.6056)	1
Δlnelc	0.0126(-3.6105)	1

NB: significant at 1% Mackinnon critical values and are shown in brackets.

Discussion of the Long-run Estimated Model

Dependent Variable: D(LNGDP)

Method: Least Squares

Date: 04/30/25 Time: 14:21

Sample (adjusted): 1981-2023

Included observations: 37 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.096703	0.470022	-4.460860	0.0001
D(LNGDP(-1))	-0.291895	0.140253	-2.081201	0.0470
D(LNGDP(-3))	-0.348209	0.138965	-2.505726	0.0186
D(LNGDP(-4))	-0.654946	0.155630	-4.208366	0.0003
D(LNCO2(-2))	0.548116	0.302082	1.814461	0.0807
D(LNCO2(-3))	1.723170	0.320044	5.384173	0.0000
D(LNCO2(-4))	0.435423	0.333673	1.304939	0.2029
LNCO2(-1)	-1.282699	0.196664	-6.522285	0.0000
LNECON(-1)	2.225026	0.414055	5.373752	0.0000
LNELC(-1)	0.024858	0.191808	0.129598	0.8978

R-squared 0.718317 Mean dependent var 0.021547 Adjusted R-squared 0.624423

S.D. dependent var 0.108038

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S.E. of regression	0.066210	Akaike info criterion	-2.366503
Sum squared resid	0.118363	Schwarz criterion	-1.931120
Log likelihood	53.78030	Hannan-Quinn criter.	-2.213010
F-statistic	7.650274	Durbin-Watson stat	2.069278
Prob(F-statistic)	0.000017		

Long-Run Model Results After Removing Most of the Insignificant Lag Variables. Source; Extracted from E views.

The paper analyses the long run impact of carbon emissions, energy consumption and economic growth in Nigeria between 1981 and 2023. The long run independent variables are LNCO2 (-1), LNECON (-1), and LNELC (-1) representing carbon emissions, energy consumption and electricity consumption respectively. The constant or intercept of the model is represented by C while the D (LNGDP) which is gross domestic product is the dependent variable. Apriori, it was expected that the signs of all the three independent variables were going to be positive, but it turns out that from the estimated model, the intercept and the coefficients of carbon emissions are negative. This means that one percentage change in carbon emissions will lead to a decrease in the percentage of GDP.

The results revealed that electricity consumption and energy consumption has a long run positive impact on GDP. Energy consumption is significant while electricity consumption is insignificant, this is not surprising given the epileptic power supply in Nigeria. Co2 is statistically significant but negatively related to GDP in the long run. The results for co2 is inconsistent with that of Nnaji et al (2013) and Akpan (2012) in the case of Nigeria. Manyah and Wolde-Rufael (2010) who conducted the same study in South Africa where co2 have been found to have an increasing relationship with GDP.

The bound test was conducted to ascertain if there exist a long run relation between the independent variables and the dependent variable using wald test, the test shows that both at 1% and 5% significant level of critical bound values by Peseran, the F statistics obtained from the wald test is greater than the upper bound values which indicates the presence of strong cointegration relationship in the long run among the dependent and independent variables in the model.(results are presented in the appendix).

The LM results shows that there is no presence of autocorrelation in the model which is very healthy for the regression. The stability test also revealed that the model is stable, this is because from the graph the blue line in the centre did not go outside the red lines.(see results and graphs in the appendix).

Discussion of the Short Run Model

Dependent Variable: D(LNGDP)

Method: Least Squares

Date: 04/30/25 Time: 15:14

Sample (adjusted): 1981-2023 ~~Included observations:~~ 38 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
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C	-0.034268	0.046682	-0.734071	0.4688
D(LNGDP(-2))	0.429211	0.186009	2.307474	0.0284
D(LNGDP(-3))	-0.126505	0.182155	-0.694488	0.4929
D(LNCO2(-2))	-0.812452	0.556677	-1.459468	0.1552
D(LNCO2(-3))	0.501024	0.568587	0.881174	0.3855
D(ECON(-1))	-0.027441	0.014912	-1.840141	0.0760
D(ECON(-2))	0.025200	0.021846	1.153497	0.2581
D(ECON(-3))	0.034535	0.023129	1.493133	0.1462
ECT(-1)	-0.035298	0.076054	-0.464124	0.6460

R-squared	0.354943	Mean dep endent var	0.021943	Adjusted R-squared	0.176996	S.D. dependent var	0.106596
S.E. of regression	0.096703	Akaike info criterion	-1.630944				
Sum squared resid	0.271194	Schwarz criterion	-1.243095				
Log likelihood	39.98794	Hannan-Quinn criter.	-1.492951				
F-statistic	1.994656	Durbin-Watson stat	1.546642	Prob(F-statistic)	0.083156		

The short run model is run with the error correction term derived from the OLS model of the long run equation. The model above is used to determine if there is a short run relationship between the independent and the dependent variable. From the model none of the variables are significant implying that that all the three variables have no short run impact on the dependent variable. Most importantly is the Error Correction Term (ECT) which measures the speed of adjustment from the short run to the long run. The coefficient of the ECT be negative and eventually it is negative in our estimated model but it is not statistically significant. The wald test (bound test) reveal that the independent have no short run impact on the dependent term.

Conclusion and Policy Implication

This paper investigates the long run and short run impacts amongst energy consumption, co2, and economic growth in Nigeria over the period of 1981-2023 using the ARDL approach to co-integration developed by Peseran et al (2001). The empirical results revealed that there is a positive and significant relationship between energy consumption and GDP while electricity consumption has a positive relationship with GDP but insignificant. On the other hand, co2 had a negative significant relationship in the estimated model.

The policy implication deduced from the study is that government should improve on electricity supply to boost economic activities vis- a- vis a subsequent significant impact on GDP. On co2 emissions the negative relationship

reveals that most of the emission are not caused by economic activities, hence the negative impact. Government should therefore, industrialise so that emissions from the industries will impact on GDP.

REFERENCES

- Akinlo, A., 2008.. Energy consumption and economic growth: evidence from 11 Sub-Sahara African countries.. *Energy Economics*, 30(5), 2391-2400.
- Alam, M. et al., 2011. Dynamic modeling of causal relationship between energy consumption, CO 2 emissions and economic growth in India.. *Renewable and Sustainable Energy Reviews*, 15(6), 3243-3251.
- Alam, M., Begum, I., Buysse, J. & Van Huylbroeck, G. (2012). Energy consumption, carbon emissions and economic growth nexus in Bangladesh: Cointegration and dynamic causality analysis. *Energy Policy*, 45, pp. 217-225.
- Alege, P., Adediran, O. & Ogundipe, A. (2015). *Pollutant Emissions, Energy Consumption and Economic Growth in Nigeria: A Multivariate Granger Causality Framework.*, Covenant University. 2nd International Conference on Africa Development Issues.
- Alkathlan, K. & Javid, M. (2013). Energy consumption, carbon emissions and economic growth in Saudi Arabia: an aggregate and disaggregate analysis. *Energy Policy*, 62, pp. 1525-1532..
- Ang, J. (2007). CO 2 emissions, energy consumption, and output in France. *Energy Policy*, 35(10), 4772-4778..
- Anietie, V. E. (2011). *The relationship between Economic growth and co2 emission and the effects of energy consumption on co2 emission patterns in a nigerian Economy.* Lagos: University of Lagos.
- Annicchiarico, B., Bennato, A. & Zanetti Chini, E. (2014). 150 Years of Italian CO2 Emissions and Economic Growth. *Journal of Economic Litreature*, pp. 1-43.
- Apergis, N. & Payne, J., 2009. CO 2 emissions, energy usage, and output in Central America. *Energy Policy*, Volume 37(8), pp. 3282-3286.
- Arouri, M., Youssef, A., M'henni, H. & Rault, C. (2012). Energy consumption, economic growth and CO 2 emissions in Middle East and North African countries. *Energy Policy*, 45, pp. 342-349.
- Arrow, K., Bolin, B., Costanza, R. & Dasgupta, P. (1995). Economic growth, carrying capacity, and the environment.. *Science*, 268(5210), 520..
- Asafu-Adjaye, J. (2000). The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. *Energy economics*, 22(6), 615-625.

Research Article

- Bahmani-Oskooee, M. & Chomsisengphet, S. (2002). Stability of M2 money demand function in industrial countries. *Applied Economics*, 34(16), 2075-2083.
- Beck & Joshi, 2015.. An Analysis of the Environmental Kuznets Curve for Carbon Dioxide Emissions: Evidence for OECD and Non-OECD Countries. *European Journal of Sustainable Development*, 4(3), .33.
- Belke, A., Dobnik, F. & Dreger, C. (2011). Energy consumption and economic growth: New insights into the cointegration relationship. *Energy Economics*, 33(5), 782-789.
- Boopen, S. & Vinesh, S. (2011). *On the relationship between CO 2 emission and economic growth. The Mauritian Experience*. Mauritius: University of Mauritius, Mauritius Environment Outlook Report.
- Bozkurt, C. & Akan, Y. (2014). Economic growth, CO2 emissions and energy consumption: the Turkish case. *International Journal of Energy Economics and Policy*, 4(3), 484..
- Bradford, D., Schlieckert, R. & Shore, S. (2001). The environmental Kuznets curve: exploring a fresh specification. *National Bureau of Economic Research.*, (No. w8001).
- Chebbi, H. & Boujelbene, Y. (2008). CO2 emissions, energy consumption and economic growth in Tunisia.. *In 12th Congress of the European Association of Agricultural Economists*, 5(1), 2023.
- Cheng, (1995). An investigation of cointegration and causality between energy consumption and economic growth.. *Journal of Energy and Development*, 21(1).
- Chindo, S. *et al.*, (2015). Energy consumption, CO2 emissions and GDP in Nigeria.. *GeoJournal*, 80(3), 315-322.
- Chiou-Wei, S., Chen, C. & Zhu, Z. (2008). Economic growth and energy consumption revisited—evidence from linear and nonlinear Granger causality. *Energy Economics*, 30(6), 3063-3076..
- Choi, E., Heshmati, A. & Cho, Y. (2010). *Empirical study of the relationships between CO2 emissions, economic growth and openness.*, s.l.: IZA DP No. 5304.
- chontanawat, J., Hunt, L. & Pierse, R. (2008). Does energy consumption cause economic growth?: Evidence from a systematic study of over 100 countries. *Journal of Policy Modeling*, 30(2), 209-220.
- Dantama, Y. U., Yahya, Z. A. & Nasiru, I. (2012). Energy consumption-economic growth nexus in Nigeria:An empirical assessment based on ARDL bound test approach. *European Scientific Journal*, 8(12).