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Economic Growth and Carbon Emissions Nexus: Evidence From Nigeria

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Abstract: With the rising climate change concerns, there have been contrasting arguments regarding the effect of economic activities on carbon emissions in a nation. The study adopted the econometric models, the Pairwise Granger Causality test, and the Autoregressive Distributed Lag model (ARDL). The ARDL bounds test for co-integration indicated that carbon emission and economic growth in Nigeria have a long-run relationship. Similarly, the long-run coefficients indicated that asides Energy Use, all independent variables have a significant effect on carbon emissions in the long run. However, the squared GDP and population growth have positive effect on carbon emissions, while GDP, trade openness, financial sector development and urbanization have negative effect on carbon emissions in the long run. Furthermore, the ECM coefficient was negative and statistically significant, meaning that in the event of any economic disequilibrium, the system will correct itself in the short run at a rate of 76 percent every quarter, eventually attaining long-term equilibrium. For the Granger Causality, result indicated that a significant bidirectional relationship exists between carbon emission and economic growth in Nigeria. It was recommended that a balance be established between carbon emission and economic growth in Nigeria by ensuring that unproductive activities that results in carbon emission are curtailed.

Keywords: Carbon intensity, Environmental Kuznets Curve, Clean technologies, Energy use.

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1. Introduction

The proliferation of industries across the globe has led to an increase in production and an increased usage of fossil fuel resulting in significant concerns regarding carbon emissions. Research shows that issues of carbon emissions constitute one of the major global concerns of the 21st century (Esso & Keho, 2016). This has led to the establishment of various laws, policies and regulations to curtail and mitigate carbon emissions internationally, regionally, nationally and locally (Climate.Gov, 2022). While the United Nations has made issues of greenhouse gas (GHG) a global priority, it is known that carbon dioxide (CO_2) and methane (CH_2) are the main contributor in the GHG emission inventory (United Nations Development Programme, UNDP, 2023). Therefore, there has been growing concerns in both advanced and less-developed countries regarding the need to effectively curtail and mitigate excessive carbon emissions, given several environmental problems associated with it.

Essentially, carbon emission as described by the United Nations refer to carbon compound (such as carbon dioxide) released into the atmosphere, often through human activity such as burning of fossil fuels such as coal or gas (Azam, Khan Bin Abdullah & Qureshi, 2016; Wang, Zhao, Fan & Zhang, 2022). Concerns regarding carbon emissions are not new and dates back to the beginning of the industrial revolution. As pointed out by International Energy Agency (IEA) (2022), carbon emissions began to rise more steeply from the 1950s and by the 2000 had reached 25.45 billion metric tons of $CO_{2.}$ However, in recent time, statistics revealed that global carbon dioxide emissions from fossil fuels and industry were 37.12 billion metric tons in 2021 (Climate.Gov, 2022). Estimations also indicates that carbon emissions are expected to rise continuously into the future, as more and more less-industrialized nations of the world become more industrialized (IEA, 2022).

However, the rise in carbon emissions have led to vast arguments and contrasting debates in the literature regarding its effects on the economy. For example, Mitić, Fedajev & Radulescu (2023) contend that carbon emissions results in warmer temperatures which causes economic losses for a country through many pathways, such as lowering agricultural yields, reducing labour productivity and decreasing output. Conversely, Gurtu, Vyas & Gurtu (2022) contend that without carbon dioxide, the earth's natural greenhouse effect would be too weak to keep the average global surface temperature above freezing. Therefore, Gurtu *et al.* (2022) further argued that by adding more carbon dioxide to the atmosphere, people are supercharging the natural greenhouse effect and ensuring a balance of temperatures.

While there are different perspectives regarding how carbon emissions impact the economy, several theories have formed basis for evaluating the interplay between carbon emissions and economic growth. One of the earliest and most employed theory is the Environmental Kuznets curve theory (EKC). The EKC is based on an inverted U-shaped curve created by Kuznets in 1955 (Khan, Khan & Rehan, 2020). It was initially designed to study the relationship between income per capita and income inequality. However, it has become more popular when it started being employed in environmental studies, particularly, those relating to carbon emission (Esso & Keho, 2016). As pointed out by Olubusoye and Musa, (2020), the EKC suggests that at the beginning of economic growth, carbon emissions, and environmental pollution increases. However, when it passes a certain level of income, the economic growth allows for environmental remediation to take place. Another theory that has formed basis for evaluating concerns of carbon emissions and economic growth, is the Economic Theory of Pollution Control (ETPC). The theory was coined by Richard Nixon when he proffered a solution to environmental problems in the 1970s (Rothman, 2017). It was coined out of the laws of thermodynamics, which is since pollution occurs because it is practically impossible to have a productive process that does not involve waste (Rothman, 2017). However, the theory has been widely adopted in most environmental studies, particularly, those relating to carbon emissions. As pointed out by Saidi & Hammami (2015), the ETPC is of the view that pollution is unavoidable in a growing economy. However, it emphasizes the need to have a balance of environmental and economic considerations in policy contexts.

Overall, despite the insights from the above theories, empirical discoveries have been conflicting. For example, empirical evidence has revealed a bidirectional causal relationship between environmental degradation (carbon emission) and economic growth (Azam et al., 2016; Ekonomou & Halkos, 2023; Esso & Keho, 2016). This implies that while carbon emissions, causes economic growth, economic growth also causes carbon emissions. Also, a study by Dogan & Seker (2016) revealed that carbon emission significantly and positively impacts economic growth, while another study by Saidi & Hammami (2015) revealed a negative interplay between carbon emission and economic growth. Given the conflicting empirical discoveries, this study aims to uncover all grey aspects in the literature, by evaluating the effect of economic growth on carbon emissions in Nigeria.

With its growing population and significant industrial capabilities, concerns have risen regarding the effect of carbon emissions on economic growth in Nigeria. The conflicting discoveries in the literature regarding the link between carbon emissions and economic growth, have further made it important to evaluate the case of Nigeria. Research shows that the economic peculiarities of each nation make them experience different outcomes with regards to certain economic concerns (Rehman & Rashid, 2017). For example, while there may be a positive impact of carbon emissions on advanced countries such as the US and UK, given their economic and structural peculiarities, such may not be realized in less-developed countries such as Nigeria and Ghana. Also, differences may still occur within less-developed countries that could have similar economic patterns and peculiarities. For example, given its nature of policies, kind of industries and number of industries, carbon emissions may be lower in Ghana than in Nigeria, thus resulting in a positive effect of carbon emissions on economic growth in Ghana and a negative effect in Nigeria. Therefore, given the high likelihood for divergence to exist in relation to carbon emissions and economic growth, it is imperative to evaluate carbon emissions concerns and how it interacts with the Nigerian economy.

Essentially, in evaluating the concerns relating to carbon emissions in the Nigerian economy, there is need to investigate the short and long run situations. Researchers (Telly, Liu & Gbenou, 2023; *Wang et al.*, 2022) argue that divergent realities could occur between the short run and long effect of carbon emissions on an economy. For example, there could be a positive effect of carbon emissions on economic growth in the short run, particularly, the fact that higher levels of carbon emissions increase income of a nation. However, it may be that in the long run, as carbon emissions increases further, there could be a decline in income given that carbon emissions could have surpassed the required level necessary for bringing about increase in income. This has been discovered to be true by various studies who discovered a positive short run effect of carbon emission on economic growth (Mirza & Kanwal, 2017; Osobajo, Otitoju, Otitoju & Oke, 2020), and a negative long run effect (Saidi & Hammami, 2015). Conversely, there may be no effect of carbon emissions in short run depending on whether the level of carbon emission is large enough to impact growth. This may ensure that only in the long run can an effect be observed of carbon emissions on an economy. Such has also been discovered to be true in studies (Goswami *et al.,* 2023; Olubusoye and Musa, 2020) which have discovered no short run effect of carbon emissions on an economy, and significant effect in the long run (Azam *et al*., 2016). However, it is yet unclear the case of Nigeria and the short run and long run interplay of carbon emissions on income in Nigeria.

Also, there is tendency that carbon emissions can cause growth and also the fact that higher levels of growth causes carbon emissions. This stems from the fact that many believe that increase in income causes emissions to rise (Nain, Ahmad & Kamaiah, 2017), while others believe that rising emissions causes increased income. However, it is unclear if rising emissions in Nigeria causes income to rise or if rising income causes emissions to rise. Although, other factors within the economy might be responsible for changing growth and not necessarily emissions, this and many others will constitute the major concerns of this study. On the converse, rising carbon emissions have been known to be an issue involving rising production and economic activities in the country.

Essentially, as described by the EKC theory and as supported by the findings of Balint, Lamperti, Mandel, Napoletano, Roventini & Sapio (2017), an increase in economic growth is a major factor that makes carbon emissions rise. Therefore, it is expected that carbon emissions react only to changes in economic growth and this has constituted the reason for the proliferation of studies on the impact of economic growth on carbon emissions. Consequently, given that most studies have only tend to focus on how economic growth increases carbon emissions (Nain *et al.*, 2017; Osadume and University, 2021), this study seeks to take a different approach by evaluating the effect of economic growth on carbon emissions. The study focus on the Nigerian economy and investigate the interactions of emissions and economic activities with a view to providing requisite recommendations for improved future outcomes. This study aims to examine the effect of economic growth on carbon emissions in Nigeria and will cover 32 years period ranging between 1990 and 2021.

2. LITERATURE REVIEW

2.1. Theoretical Review

2.1.1. Environmental Kuznets Curve (EKC)

In 1991, Grossman and Krueger (1991) found that the long-term relationship between economic growth and environment quality was an inverted U-shaped curve. The phenomenon has been labeled as Environmental Kuznets Curve (EKC) by Panayotou (1993) later. The EKC hypothesizes that environment quality deteriorates with the increase of per capita income at the early stage of economic growth and gradually improves when the country reaches to a certain level of affluence. Developed countries have fairly stable production structures, whereas rapidly industrializing and developing countries have unstable production structure and the effects of structural change on emissions may be less obvious. The primary sector (agriculture, fisheries, forestry, and mining) tends to be more resource-intensive than either the secondary (industry) or tertiary (services) sectors. The industry (specially manufacturing), on the other hand, tends to be more pollution-intensive than either agriculture or services. Since the structure of the economy (sectoral composition of output) changes with economic growth, part of the effect of increases in income per capita on environmental degradation reflects the effects of changing composition of output. In the case of pollution, economic structure is represented by the share of industry in GDP and expects a positive relationship with environmental degradation. Since the share of industry in GDP first rises with economic growth and then declines as the country moves from the pre-industrial to the post-industrial stage of development, an Inverted-U shaped relationship between environmental pollution and income level are expected while controlling for all other influences transmitted through income.

The importance of trade in combination with composition of economic activity is investigated in the decomposition of EKC for CO_2 concentrations across countries (Zoundi, 2017). People, at low-income levels, are more concerned with food and other material needs and less concerned with environmental quality. People, at higher income levels, begin to demand higher levels of environmental quality to go along with their increased prosperity. The modified EKC analysis can be used to compare the differences in EKC between countries (developed and developing specifically, if enough data exists) due for instance to inter-country variations in the presence of corruption. One of the determinants of environmental policy is the socio-political regime of a particular country. Corruption and rent-seeking behaviour can influence the relationship between income and environment (Alaganthiran & Anaba, 2022). However, for any level of per capita income, the pollution levels corresponding to corrupt behavior are always above the socially optimal level. So, the turning point of EKC takes place at income and pollution levels above those corresponding to the social optimum, which depends on the existing social institutions. Institutional changes triggered by citizens' demand for cleaner environments are more likely to occur in developed countries than in developing.

2.1.2. Halo Effect Hypothesis

The Halo effect follows the productivity literature, which examines the productivity spillovers by FDI both at the firm and macroeconomic levels. The rationale behind potential environmental spillovers is the possibility that multinational corporations (MNCs) encourage the dissemination of environmentally clean technologies and management practices (Khoshnevis & Dariani, 2019). This occurs if the foreign firm engages in contracts only with environmentally responsible domestic counterparts. This may happen under shareholder pressure at the MNC or because of practices established at the MNCs based on its home country environmental regulations and standards. Further environmental knowledge can disseminate through the movement of trained workers from foreign to domestic firms or because of a direct competition of domestic firms with the MNCs. The literature on environmental spillovers from FDI confines to only case studies of specific countries' manufacturing industry firms. The evidence with respect to the halo hypothesis has been mixed (Aye & Edoja, 2017).

2.1.3. Pollution Haven Hypothesis

The original pollution haven hypothesis states that as trade is liberalized, industries that pollute shift from rich countries with tight regulation to poor countries with weak regulation and conversely, clean industries migrate towards rich countries (Khobai &

Le Roux, 2018). The pollution haven hypothesis has three dimensions. The first is the relocation of heavy polluting industries from developed countries with stringent environmental policies to developing countries where similar policies do not exist, are lax or not enforced. Accordingly, global free trade would encourage polluting industries and processes to move to countries with weak environmental policy. The second dimension is the dumping of hazardous waste generated from developed countries (industrial and nuclear energy production), in developing countries. This issue was the subject of the Basle Convention on hazardous waste. The last dimension is the unrestrained extraction of non-renewable natural resources in developing countries by multinational corporations engaged in producing petroleum and petroleum products, timber and other forest resources, etc. All the dimensions relate to conscious decisions on environmental policy and how they impact on the environment, future production and trade (Mikayilov *et al.*, 2018).

This theory addressed pollution haven in three ways. (i) The relation between exports and regulation. Since regulation increases cost, the exports of countries with more stringent regulations become relatively more expensive than those with lax regulation. Therefore, their exports decline and their imports of relatively dirty goods rise. (ii) The shift in the pattern of trade in pollution-intensive goods: despite evidence supporting this hypothesis (Bilan *et al.*, 2019), this may be due to various factors such as increase in demand for products in the developing countries, development of endowments that develop these industries. (iii) Accordingly, high regulatory costs are likely to deter firms' investment decisions. At the international level, the specific question that is addressed is whether FDI in polluting industries increased towards developing countries (Gün, 2019).

2.1.4. Pollution Leakages

Pollution leakage has emerged as a potentially important factor in the relationship between economic growth and environmental quality (Bouznit & Pablo-Romero, 2016). Critics of the Environmental Kuznets Curve hypothesis have suggested that whilst economic growth in country A may lead to lower domestic emissions due to structural changes in the domestic economy, continued consumption of pollution intensive products imported from overseas may lead to increases in pollution in the exporting country (Zoundi, 2017). Moreover, measures to reduce emissions in country A – such as a pollution tax – may result in increased emissions in exporting countries, partly through changing incentives for the location of dirty industries when factors of production are mobile across international borders (Sisodia *et al.*, 2023). Modelling studies of the effects of energy efficiency improvements on domestic pollution reveal a third channel for pollution levels in trading countries to be codetermined, due to competiveness effects on energy-intensive (and thus, typically, carbon-intensive) export sectors (Mathieu *et al*, 2019).

2.2. Empirical Review

The relationship between CO_2 emission and economic growth had been studied by different researchers and they come out with different results. Baojuan, Rongrong & Ying (2011) tested the environmental quality in Tangshan and the statistics of GDP per capita from 2000 to 2009, environmental econometric model was built, and the coordination development of environmental pollution and economic growth were studied. The results show there is no obvious EKC relationship between other environmental indicators and GDP per capita of Tangshan besides industrial dark matter emission. The emissions of industrial wastewater and industrial solid waste will continue to rise.

Hitam & Borhan (2012) investigated the two most important benefits and costs of foreign direct investment (FDI) in the Malaysian context: gross domestic product (GDP) growth and environmental degradation. The non-linear model examines the relationship between foreign direct investment and environmental degradation in Malaysia during 1965 to 2010. The results indicated that environmental Kuznets curve exists, and foreign direct investment increases environmental degradation.

Azlina & Mustapha (2012) investigated the causal relationships between energy consumption, economic growth and pollutant emissions for Malaysia over the period 1970-2010. The result showed the existence of the long-run relationship between energy consumption, economic growth and emission. The results also point to a unidirectional causality running from economic growth to energy consumption, from pollutant emissions to energy consumption and from pollutant emissions to economic growth.

Mercan & Karakaya (2015) investigated the causal relationships among economic growth, energy consumption and CO_2 emissions for selected eleven OECD countries (Brasil, France, Greece, Italy, Korea Republic, Mexico, Netherland, Poland, Spain, Turkey, UK, USA) and Brasil over the period 1970-2011. In the study, firstly, Cross Sectionally Dependency (CD) in a country was examined by using CDLM test (Cross Sectionally Dependency Lagrange Multiplier) developed by Pesaran (2004). As a result of the empirical analysis, co-integration relationship between the series was determined. The findings reveal that energy consumption in the general of countries in the panel affected carbon dioxide emissions positively, on the other hand, GDP growth affected it negatively, yet the impact was rather small.

Sghari & Hammami (2016) examined the relationship between energy, pollution, and economic development in Tunisia, the study was set to understand long and short-run linkages between economic growth, energy consumption and CO_2 emission using Tunisian data over the period 1971–2004. Statistical findings indicate that economic growth, energy consumption and CO_2 emissions are related in the long-run and provide some evidence of inefficient use of energy in Tunisia, since environmental pressure tends to rise faster than economic growth. In the short run, results support the argument that economic growth exerts a positive "causal" influence on energy consumption growth. In addition, results from impulse response do not confirm the hypothesis that an increase in pollution level induces economic expansion. Although Tunisia has no commitment to reduce Greenhouse Gas emissions, energy efficiency investments and emission reduction policies will not hurt economic activities and can be a feasible policy tool for Tunisia.

Ahmed & Long (2012) used the environmental Kuznets curve (EKC) hypothesis to investigate the relationship between CO_2 emission, economic growth, energy consumption, trade liberalization and population density in Pakistan with yearly data from 1971 to 2008. The results support the hypothesis both in short-run and long-run and an inverted U-shaped relationship was found between CO_2 emission and growth. Interestingly the study found trade supports the environment positively and population contributes to environmental degradation in Pakistan. The energy consumption and growth are the major explanatory variables which contribute to environmental pollution in Pakistan.

Bildirici & Ersin (2015) investigated the causality analysis among biomass energy consumption, oil prices and economic growth in Austria, Canada, Germany, Great Britain, Finland, France, Italy, Mexico, Portugal and the U.S. The dataset covers the 1970 – 2013 period. The study focused on the relationship because it was accepted that biomass energy is affected by economic growth and the oil price. For Austria, Germany, Finland and Portugal, the Granger causality test determined the evidence that the conservation hypothesis is supported. In the U.S., the feedback hypothesis highlights the interdependent relationship between biomass energy consumption and economic growth. Tado Yamamoto test determined, for Austria, Germany, Finland and Portugal, the conservation hypothesis is supported. In the U.S., the feedback hypothesis highlights the interdependent relationship between biomass energy consumption and economic growth.

Bildirici (2016) analysed the relationship between economic growth and hydropower energy consumption. According to the results of the short-run causality, there was evidence to support the growth hypothesis in OECD countries with high incomes. There was evidence to support the conservation hypothesis for Brazil, Finland, France, Mexico, the U.S. and Turkey. The unidirectional causality goes from economic growth to energy consumption and suggests that the policy of conserving hydropower energy consumption may be implemented with little or no adverse effects on economic growth in less energy-dependent economies.

Chang (2017) examined the linkage between energy use (coal) and economic growth within the BRICS countries in 1985-2009. The study found a unidirectional causality running from energy use to economic growth in China, and from economic growth to energy use in African countries. ANG (2007) applied a co-integration approach to examine the dynamic relationship between economic development, energy consumption and pollution. The study found a short-term unidirectional causality from energy use to economic growth. Omisakin, (2009) tested the EKC hypothesis for CO_2 with annual data of CO_2 per capita and GDP per capita from 1970-2005. The study found no long-run relationship between carbon emissions per capita and income per capita in Nigeria. The result, on the other hand, depicted a U-shaped income environment relationship rather than an inverted U shaped, contradicting the EKC hypothesis.

Bello & Abimbola, (2010) found no evidence of an Inverted-U shaped relationship between income and the environment in Nigeria. The study applied time series data from 1980- 2008 in Nigeria. The study concluded that carbon emission in Nigeria is not driven by economic growth but rather driven by financial developments such as Foreign Direct Investment (FDI). This is because the study found that economic development does not have any influence on CO_2 emissions in Nigeria. Fodhaet, (2010) investigated the relationship between economic growth and the environmental degradation for a small developing country, Tunisia. The study used time series data from the period 1961-2004 with CO_2 and SO_2 as the environmental indicators and GDP as the economic indicator. The study results showed that there is a long run cointegration relationship between per capita GDP and the per capita emissions of the two pollutants (CO_2 and SO_2) but the relationship between CO_2 emissions and GDP was found to be more monotonically increasing as compared to that between SO_2 and GDP. The study further tested the causal relationship between income and pollution and found that, the relationship between the two in Tunisia is unidirectional both in the short and long run implying that, income causes environmental damages and not vice versa.

Aye & Edojo (2017) investigated the nexus between economic growth and carbon dioxide (CO_2) emission using the dynamic panel threshold framework using data from a panel of 31 developing countries. The findings from the study indicate that economic growth has a negative effect on CO_2 emission in the low growth regime but positive effect in the high growth regime with the marginal effect being higher in the high growth regime. The finding however provides no support for the Environmental Kuznets Curve (EKC) hypothesis; but a U-shaped relationship is established. Energy consumption and population were also found to exert a positive and significant effect on CO_2 emission. Financial development indicator in the model did not change the conclusion about the EKC hypothesis. The employment of panel causality methods evidenced a significant causal relationship between CO_2 emission, economic growth, energy consumption and financial development. The findings emphasize the need for transformation of low carbon technologies aimed at reducing emissions and sustainable economic growth. This may include energy efficiency and switch away from nonrenewable energy to renewable energy.

Applying the panel unit root tests, panel co-integration methods and panel causality test, Farhani & Rejeb (2012) investigated the relationship between energy consumption, GDP and CO_2 emissions for 15 MENA countries using data from 1973–2008. The finding of this study revealed that there is no causal link between GDP and energy consumption; and between CO_2 emissions and energy consumption in the short run. However, in the long run, there is a unidirectional causality running from GDP and CO_2 emissions to energy consumption. Saidi & Hammami (2015) analyzed the impact of economic growth and CO_2 emissions on energy consumption for a global panel of 58 countries for the period 1990–2012. Similar analysis was conducted for three regional panels, namely, Europe and North Asia, Latin America and Caribbean, and Sub-Saharan, North African and Middle East. The results indicate significant positive impact of CO_2 emissions and economic growth on energy consumption for the four global panels. The impact of financial development, capital stock and population on energy consumption were also positive and mostly significant.

Kasman & Duman (2015) employed panel unit root tests, several panel co-integration methods such as the Kao, Pedroni, Westerlund tests specifically, and panel causality tests (panel-based error correction model) to examine the causal relationship between energy consumption, CO_2 emissions, economic growth, trade openness and urbanization for a panel of 15 new EU member and candidate countries over the period 1992–2010. Their results provide evidence supporting the EKC hypothesis. The results also indicate that there is a short-run unidirectional panel causality running from energy consumption, trade openness and urbanization to CO_2 emissions. The results of the long-run causal relationship showed that carbon dioxide emissions, energy consumption, GDP and trade openness are important in the adjustment process as the system departs from the long-run equilibrium.

Al-mulaliTang & Ozturk (2015) studied the effect of economic growth, renewable energy consumption and financial development on CO_2 emission in 18 Latin America and Caribbean countries for the period1980–2010. The Kao co-integration test results revealed that the variables are co-integrated. Using the fully modified ordinary least square (FMOLS) method, the results indicated an inverted U-shape relationship between CO_2 and GDP. Also financial development had a negative long run effect, energy consumption had no long-run effect on CO_2. The VECM Granger causality results revealed feedback causality between GDP, electricity consumption from renewable sources, financial development and CO_2 in both short-and long-run. Additionally, Granger causality results also revealed that electricity consumption, GDP, and financial development can be a good solution to reduce environmental damage since they have a causal effect on CO_2.

Magazzino (2016) investigated the relationship between CO_2 emissions, economic growth, and energy use for 10 Middle East countries over the period 1971–2006 using a panel VAR. Both the estimated coefficients and impulse response functions show that for the six GCC countries the response of economic growth to CO_2 emissions is negative. CO_2 emissions seem to be driven both by its own past values and by energy use. For the other four non-GCC countries, neither CO_2 emissions nor energy use seems to have an impact on growth, which is determined by its own lagged values.

Kais & Ben Mbarek (2017) investigated the causal relationship between energy consumption, carbon dioxide (CO_2) emissions and economic growth for three selected North African countries based on data covering1980–2012. Using a panel co-integration test they found interdependence between energy consumption and economic growth in the long run. Results based on panel Vector Error Correction Model, detect unidirectional relationship from economic growth to energy consumption, a unidirectional causality running from economic growth to CO_2 and a unidirectional causal relationship from energy consumption to CO_2 emissions. Using data from 1971–2013 on five selected economies of South Asia, Ahmed *et al.* (2017) explored the relationship between CO_2 emission, energy consumption, income, trade openness and population. All the panel co-integration tests (Pedroni- Kao- and Johansen-Fisher panel co-integration) employed confirm that all the variables were co-integrated. Using FMOLS, the results show that energy consumption, trade openness and population increases environmental degradation has negative impact. Further, results indicate that there is uni-directional causality running from energy consumption, trade openness and population to CO_2 emission.

Saidi & Hammami (2016) investigated the impact of economic growth and CO_2 emissions on energy consumption for a global panel of 58 countries for the period

1990–2012. The study also estimates this relationship for three regional panels: namely, from Europe and North Asia, Latin America and Caribbean, and Sub-Saharan, North African and Middle Eastern. The empirical evidence indicated significant positive impact of CO_2 emissions on energy consumption for four global panels. Economic growth has a positive impact on energy consumption and statistically significant only for the four panel.

Adu & Denkyirah (2017) tested the environmental Kuznets curve (EKC) hypothesis by analyzing the relationship between economic growth and environmental pollution (carbon dioxide emission, CO_2 and combustible renewable waste, CoWaste) using a panel dataset from 1970 to 2013 for selected West African countries with similar income status. The results revealed that economic growth in the short-run significantly increases CO_2 emissions and CoWaste but does not significantly decrease CO_2 emission and CO_2 waste in the long-run. The non-significant relationship between economic growth and environmental pollution indicates the non-existence of EKC in West Africa. The results of the study further revealed a very low turning point at which CO_2 emission and CoWaste start to decrease; however, the non-existence of the EKC implies that the relationship between economic growth and environmental degradation in West African countries cannot be explained by an inverted U-shaped curve. The study recommends that West African economies should pursue efficiency improvement policy intervention to prevent environmental degradation.

Khoshnevis and Dariani (2019) investigated the causal relationship between carbon emissions, energy consumption, economic growth, trade openness and urbanization for Asian countries for the period from 1980 to 2014. The study employed pooled mean group (P.M.G) approach and panel Granger causality tests. The findings from the Pedroni panel cointegration test suggested an existence of a long run relationship among the variables. The Granger causality results revealed bidirectional causality flowing between economic growth, urbanization and CO_2 emissions. Vo and Le (2019) study served to determine the causal relationship between carbon dioxide emissions, energy consumption, renewable energy, population and economic for countries for five ASEAN member countries (Indonesia, Myanmar, Malaysia, the Philippines, and Thailand) covering the period 1971-2014. The results showed that there is a long run relationship among the variables only for Indonesia, Myanmar and Malaysia. It is further discovered that the EKC hypothesis is validated in Myanmar but not in Malaysia and Indonesia. Neutrality hypothesis was established among the variables for Malaysia, Thailand and the Philippines but one-way causality flowing from economic growth to carbon emission and energy consumption was established in Indonesia. In Myanmar a unidirectional causality flowing from economic growth, energy consumption and population to renewable energy. Mathieu et al. (2019) investigated the relationship between energy consumption, carbon emissions and economic growth in Togo. Using the ARDL model, the study found that there is a long relationship among the variables. Osobajo et al. (2020) served to assess the impact of energy consumption and economic growth on carbon dioxide emissions for 70 countries covering the period between 1994 and 2013. The results suggested a long run relationship between the variables. The pooled OLS and fixed method revealed that energy consumption and economic growth have a positive effect on carbon emissions.

Khan *et al.* (2020) conducted a study to assess the relationship between energy consumption, carbon dioxide emissions and economic growth in Pakistan covering the period between 1965 and 2015. Their findings from the ARDL bounds test revealed that economic growth and energy consumption increase carbon dioxide emission both in the long run and short run. Olubusoye and Musa (2020) focused on 43 African countries to test if there is a relationship between Economic growth and Carbon emissions. The findings suggested that in 79% of the countries, carbon emissions increase as economic growth increases while 21% of the countries showed a negative relationship between economic growth and carbon emissions. Osadume (2021) served to examine the impact of economic growth on carbon emissions on six selected West African countries covering the period from 1980 to 2019. To do statistical analysis, the study used panel econometric methods. It was established that there is a long relationship among the variable and economic growth a positive and significant effect on carbon dioxide emissions in the short run.

The study by Okijie & Effiong (2021) was geared towards examining the influence of urbanization, population growth and economic development in Nigeria with the use of data from 1961 to 2014. The study made use of the OLS, VAR and threshold regression analysis to establish the relationship among the variables. Key findings from the study is that the EKC hypothesis is valid in Nigeria within the study period. Further, it was established that both population growth and urbanization exerted a positive and significant effect on carbon intensity in Nigeria.

Alaganthiran & Anaba (2022) explored energy consumption, tourism sector and population effect on carbon dioxide emissions. The study employed panel linear regression model and secondary data from 20 Sub Saharan African (SSA) countries from 2000 and 2020. The empirical estimation techniques employed in the analysis consist of pooled ordinary least square (OLS), fixed effects model (FEM), random effects model (REM) and robust fixed model, including diagnostic tests such as endogeneity, heteroscedasticity and other measurements. The empirical analysis using the robust fixed effects model has established significant associations between economic growth, energy consumption, tourism sector and population on carbon dioxide emissions in SSA countries between 2000 and 2020. This study has established that a 1% increase in economy growth increases the carbon dioxide emission level by approximately 0.02%. A study has identified that SSA countries' energy consumption, especially from oil, will only contaminate air quality. The study recommended for better policies targeted at controlling population in order to ensure reduced carbon emissions.

Also, Khobai & Sithole (2022) explored the relationship between economic growth and carbon emissions in South Africa covering the period between 1984 and 2018. The study employed the ARDL bounds technique to determine the long run relationship among the variables and the VECM to determine the direction of causality among variables. The findings established that there is a long relationship between carbon emission, economic growth, energy consumption, foreign direct investment, and trade openness in South Africa. The VECM suggested that there is bidirectional causality flowing between economic growth and carbon emissions. The results also validated the EKC hypothesis both in the long run and short run. Overall, the study argued that it is imperative for the policy makers and government to divert their thoughts to more innovative and creative strategies of attaining alternative energy sources especially renewable sources.

Sisodia *et al.* (2023) investigated the long-run effect of carbon emission and economic growth in European Countries a computational analysis through Vector Error Correction Model. The examination of variables captured twenty-one years of data from 2000 to 2020 using a multidimensional data framework. The findings come from empirical analysis carried out using panel VECM model and associated tests such as, panel unit root test, cointegration and the causality one. It was discovered that the different variables indicated above have positive effects on the growth of economies in various EU member states. Also, results obtained from the use of the heterogeneous causality test indicated that there was an indirect causality between energy use and the rate at which economies develop. Based on the findings, it was recommended that there is a need for EU member states to establish policies that should help to enhance efficiency in energy use to promote economic development.

Recently, Effiong, Akpan & Inyang (2024) explored the influence of energy utilization, financial sector development, and economic growth on carbon emissions in West Africa. The study utilized panel data covering the periods 1995–2014 and 1995–2022 for some variables due to the availability of data for twelve (12) West African countries. The study was based on the framework of the Environmental Kuznets Curve (EKC) hypothesis. The data analysis follows the cointegrating regression analysis under the fully modified ordinary least squares (FMOLS) approach. The findings of the study indicated that the EKC hypothesis is valid within the West African region. Further, financial development and energy utilization were observed to exert a positive and significant effect on carbon emissions in West Africa.

3. Methodology

3.2. Model Specification

This model employed in this study is based on the EKC model. The EKC hypothesis suggests that the environmental pollution increases at the beginning of economic growth. However, when it passes a certain level of income, the economic growth allows environmental remediation. The model adopted in this study is based on the work of Alaganthiran & Anaba (2022) who evaluated the impact of economic growth on carbon emissions in Selected Sub-Saharan Africa. The model is adopted with slight modifications as follows.

The functional form of the model is given as:

$$CE = f\,(GDP, GDP^2, ENU, TOP, FDV, POP, URB) \qquad (3.1)$$

Where CE = CO_2 emissions metric tons per capita (proxy for carbon emission); TOP = value of total import plus total export divided by GDP (proxy for trade openness); GDP = Annual GDP growth (%); GDP^2 = Annual GDP growth (% Squared) which measures the non-linear relationship; ENU = Energy Use; FDV = Financial Development (ratio of broad money supply to GDP); POP = Annual Population Growth rate; and URB = Urbanization (% of Urban Population Annual Growth)

The econometric function of the model is given as:

$$CE_t = \beta_0 + \beta_1 GDP_t + \beta_2 GDP^2_t + \beta_3 ENU_t + \beta_4 TOP_t + \beta_5 FDV_t + \beta_6 POP_t + \beta_7 URB_t + \mu_t \qquad (3.2)$$

Where β_0 is the constant or intercept of the model, $\beta_1 - \beta_7$ are the slope parameters to be estimated, μ is the error term also known as the stochastic disturbance term or random term, while t represents the period covered by the study.

3.3. A Priori Expectation

Based on the EKC theory, increase in economic activities is associated with rising carbon emissions and thus a positive relationship is expected between carbon emission and economic growth ($\beta_1 > 0$; $\beta_2 < 0$) Also, it is expected that other variables (ENU, TOP, FDV, POP and URB) will have a positive relationship with carbon emissions in the country.

3.4. Nature and Sources of Data

The data used in this study are annual time series secondary data on the variables covering a 32-year period from 1990 to 2021 obtained from World Development Indicators and they were data on variables including CE, GDP, POP, FDV, URB, TOP and ENU.

3.5. Variable Description

Carbon Emissions (CE): Carbon dioxide emissions or CO_2 emissions are emissions stemming from the burning of fossil fuels and the manufacture of cement; they include carbon dioxide produced during consumption of solid, liquid, and gas fuels as well as gas flaring. The CE serves as the dependent variable in this study.

Trade Openness (TOP): This is measured as the sum of a country's exports and imports as a share of that country's GDP.

Energy Use (ENU): This is the amount of energy utilized in the various economic activities in a country, including for residential, commercial, transportation and industrial.

Financial Development (FDV): Financial development is the development of financial institutions, financial markets, and financial instruments. It involves funding of entrepreneurial activity and innovations.

Annual Population Growth (POP): This is an increase in the number of people that reside in a country, state, county, or city.

Urbanization (URB): This refers to total population in the urban areas at a time relative to the total population at that given time.

Gross Domestic Product (GDP): This is the annual market value of all final goods sold and services paid for inside a country at a given time.

3.6. Method of Data Analysis

3.6.1. Unit Root Test

This is the Pre Cointegration test. It is used to determine the order of integration of a variable, that is how many times it has to be different or not to become stationary. It is to check for the presence of a unit root in the variable i.e., whether the variable is stationary or not. The null hypothesis is that there is no unit root. This test is carried out using the Augmented Dickey Fuller (ADF) technique of estimation. The rule is that if the ADF test statistic is greater than the 5 percent critical value we accept the null hypothesis i.e., the variable is stationary but if the ADF test statistic is less than the 5 percent critical value i.e., the variable is non-stationary we reject the null hypothesis and go ahead to difference once. If the variable does not become stationary at first difference, we differ twice. However, it is expected that the variable becomes stationary at first difference. The general form of this test is estimated in the following forms:

$$\Delta Yt = \beta_0 + \beta Y_{t-1} + \mu_1 \Delta Y_{t-1} + \mu_2 \Delta Y_{t-2} + \ldots + \mu p \Delta Y_{t-p} + e_t \quad (3.3)$$

Where Y_t represents time series to be tested, β_0 is the intercept term, β is the coefficient of interest in the unit root test, μ is the parameter of the augmented lagged first difference of Y_t to represent the pth order autoregressive process, and e_t is the white noise error term.

3.6.2. Autoregressive Distributed Lag (ARDL) Model

The ARDL method is mostly adopted when the variables are found to be a combination of order zero and order one, without the presence of order two. The Autoregressive Distributed lag (ARDL) is used to establish evidence of co-integration between the dependent variable and independent variables. The bound test technique will thus be used to test for cointegration in the long run. The choice of the lag will be decided based on the Schwarz Information Criteria, Hannan Quinn information criterion and Akaike Information Criteria, while other diagnostic test will be conducted to confirm the appropriateness of the ARDL technique. Following Pesaran *et al.* (2001), the ARDL approach to cointegration is done as shown in Equation (3.4).

$$\Delta CE_t = \beta_0 + \beta_1 GDP_t + \beta_2 GDP_t^2 + \beta_3 ENU_t + \beta_4 TOP_t t + \beta_5 FDV_t + \beta_6 POP_t + \beta_7 URB_t + \sum_{t=1}^{p} \beta_8 \Delta CE_{t-i} + \sum_{t=1}^{q} \beta_9 \Delta GDP_{t-i} + \sum_{t=1}^{q} \beta_{10} \Delta GDP^2{}_{t-i} + \sum_{t=1}^{q} \beta_{11} \Delta ENU_{t-i} + \sum_{t=1}^{q} \beta_{12} \Delta TOP_{t-i} + \sum_{t=1}^{q} \beta_{13} \Delta FDV_{t-i} + \sum_{t=1}^{q} \beta_{14} \Delta POP_{t-i} + \sum_{t=1}^{q} \beta_{15} \Delta URB_{t-i} + \theta ECT_{t-1} + \mu \quad (3.4)$$

Where θ is the error correction term which is expected to be negative and statistically significant for the model to adjust to long run equilibrium.

3.6.3. Granger Causality Model

This study employs the Granger causality test to investigate whether carbon emission Granger causes economic growth or vice versa and if there exists such a relationship, whether it is unidirectional or bidirectional or no causality and also the nature of the direction of causality. The pairwise Granger causality regression models are specified with the following equations below.

$$CE_t = \sum_{i=1}^{p} \alpha_{1j} GDP_{t-i} + \sum_{j=1}^{p} \alpha_{2j} CE_{t-j} + \varepsilon_t \quad (3.5)$$

$$GDP_t = \sum_{i=1}^{p} \beta_{1j}\, CE_{t-1} + \sum_{j=1}^{p} \beta_{2j}\, GDP_{t-1} + \varepsilon_t \qquad (3.6)$$

The test generates the F-statistics which are being tested for significance. The null hypothesis is that GDP does not Granger cause CE. The significance of the F-statistic at the 5% level will prompt the rejection of the null hypothesis.

4. Empirical Findings

4.1. Descriptive Statistics

The summary of various statistics of the variables employed are presented in Table 4.1.

Table 4.1: Summary Statistics

Statistic	*GDP*	*GDP²*	*CE (%)*	*ENU*	*FDV*	*URB*	*TOP*	*POP*
Average	4.32	34.30	0.68	732.43	17.94	4.50	36.16	2.60
Std. Deviation	4.02	47.56	0.12	30.70	6.07	0.41	9.39	0.10
Maximum	15.33	234.98	0.92	785.26	27.38	5.49	53.28	2.76
Minimum	-2.04	0.01	0.49	680.06	9.06	3.91	16.35	2.41
Skewness	0.44	2.74	0.32	-022	0.08	0.47	-0.16	-0.08
Kurtosis	3.29	11.47	1.84	1.76	1.37	2.09	2.47	1.84
Jarque-Bera (JB)	1.12	135.88	2.35	2.29	3.56	2.29	0.51	1.84
Probability	0.57	0.00	0.31	0.32	0.17	0.32	0.77	0.40
Observation	32	32	32	32	32		32	32

Source: Researcher's Computation

The average value of GDP (4.32) is closely linked with its standard deviation value (4.02) which shows a high level of deviation from the average value. The average value of CE (0.68) differs significantly from its standard deviation value (0.12) indicating low deviation of the values from the average value. Same can be said for URB with an average value of 4.50 and a corresponding standard deviation value of 0.41 indicating low deviation from the average value. GDP^2 has an average value of 34.30 with a very high standard deviation of 47.56 indicating high level of deviation from the average value. ENU has an average value of 732.43 and a low standard deviation value of 30.70. FDV has an average value of 17.94 and a standard deviation value of 6.07 indicating low deviation from the mean value. POP has an average value of 2.60 and a low standard deviation value of 0.10. TOP has an average value of 36.16 and a standard deviation of 9.39, indicating a low deviation of the values from the average value. Furthermore, the positive results of the Skewness statistic indicated that all of the variables except ENU, TOP and POP were positively skewed toward normality. The Kurtosis value demonstrates that none of the variables are leptokurtic, as demonstrated by the positive Kurtosis statistic. The result also indicated that all the variables were normally distributed given that their respective probability values were greater than the conventional 5% significance level. Overall, the entire observation was found to be 32 in total indicating a time trend of 32 years.

4.2. Correlation Analysis

Often considered bivariate, correlation analysis is primarily concerned with determining whether a relationship exists between variables and then determining the magnitude and direction of that relationship (Efiong, Ayuk and Imong, 2018). The popularity of correlation analysis in research endeavors stems from the fact that it provides a means of knowing the connections between variables and information about those connections can provide new insights and reveal interdependencies, as well as aid in problem solving (Havi, 2019). This study employed the Pearson Coefficient of correlation in examining the association between the variables employed in the study. The correlation analysis is presented in Table 4.2.

Table 4.2: Correlation Analysis Table

Variables	*CE (%)*	*GDP (%)*	*GDP^2 (%)*	*TOP (%)*	*ENU (%)*	*FDV (%)*	*URB (%)*	*POP (%)*
CE	1							
GDP	-0.063	1						
GDP^2	-0.010	0.675	1					
TOP	0.321	0.381	0.161	1				
ENU	-0.611	0.028	-0.077	-0.261	1			
FDV	-0.316	-0.165	-0.191	-0.399	0.670	1		
URB	-0.165	0.794	0.707	0.329	0.094	-0.118	1	
POP	-0.222	0.645	0.487	0.520	0.109	-0.037	0.626	1

Source: Researcher's Computation (2023)

It is observed that CE is negatively correlated with GDP (-0.063), GDP^2 (-0.010), ENU (-0.611), FDV (-0.316), URB (-0.165) and POP (-0.222) and positively correlated with TOP (0.321). The results further revealed that there was no concern for multicollinearity as indicated by the fact that all correlation coefficients in the model were below 0.8.

Overall, the table above shows that the entire model is free from a high level of relationship between the variables, and thus, signifies that the study is free from any form of simultaneous bias that could lead to spurious regression results.

4.3. Unit Root Test

The ADF test for unit root was used to evaluate if time series data were stationary or non-stationary, as well as the number of times (the level) at which the variables must be differentiated before becoming stationary. GDP and GDP^2 were stationary at level and therefore considered I(0) series. However, CE, TOP, ENU, FDV, URB and POP were all stationary after first differencing, indicating that they are I(1) series. the result is presented in Table 4.3.

Table 4.3: Unit Root Test Results

Variables	*ADF T-Statistics*	*Probability Value*	*Level of Integration*
CE	-5.544	0.000*	I(1)
GDP	-3.626	0.011*	I(0)
GDP^2	-4.781	0.006*	I(0)
TOP	-5.422	0.000*	I(1)
ENU	-5.316	0.000*	I(1)
FDV	-4.487	0.001*	I(1)
URB	-8.385	0.000*	I(1)
POP	-4.065	0.004*	I(1)

Note: *indicates significant at 5% critical level
Source: Researcher's Computation (2023)

Based on Table 4.3, all the variables employed in this study were stationary either at level or after first difference, justifying the use of the Autoregressive Distributive Lag approach (ARDL). To begin, we must determine whether the variables are cointegrated. To accomplish so, we use the ARDL bounds test for cointegration, which is described in the next section.

4.4. ARDL Co-integration Test

The ARDL co-integration test is conducted in order to evaluate the existence or non-existence of a long run relationship between carbon emission and economic growth in Nigeria. The summary of the test is presented in table 4.4.

Table 4. 4: ARDL Bounds Test for Co-integration

Model		*F-Statistic = 4.774*
CE = f(GDP, GDP^2, TOP, ENU, FDV, URB, POP)		K = 7
Critical Values	Lower Bound I(0)	Upper Bound I(1)
10%	2.28	3.50
5%	2.73	4.16

Source: Researcher's Computation (2023)

The co-integration test is presented in table 4.4 above and it indicates that the F-statistic of 4.77 is higher than the lower and upper bounds critical value at both the 5% and 10% levels of significance in the co-integration test with CE as the dependent variable. This suggests that a long run relationship exists between carbon emissions and economic growth in Nigeria. As a result, the study rejects the null hypothesis, which argues that there is no substantial long-run relationship between carbon emissions and economic growth in Nigeria, and accepts the alternative, which states that there is a significant long-run relationship. Overall, given the existence of a long-run relationship between the variables, the long run coefficients are summarized in the next section below.

4.5.ARDL Long Run Coefficients

Having established the existence of a long run relationship, the study went further to examine the long run coefficients. This was imperative to evaluate the long run effect of carbon emissions on economic growth in Nigeria. The summary of the long run coefficients is described in the table below;

Table 4. 5: ARDL Long run Estimates

Dependent Variable: CE

Variable	*Coefficient*	*Std. Error*	*t-Statistic*	*Probability*
GDP	-0.027	0.011	-2.470	0.039
GDP^2	0.006	0.001	4.395	0.002
TOP	-0.010	0.004	-2.780	0.024
ENU	0.001	0.001	0.908	0.390
FDV	-0.023	0.004	-5.474	0.001
URB	-0.838	0.208	-4.024	0.004
POP	2.260	0.568	3.979	0.004
C	-1.370	0.916	-1.494	0.173

Source: Researcher's Computation (2023)

Table 4.5 shows that the intercept term (C) was negative and statistically insignificant at the 5% level given a probability value of 0.17. This indicates that if all the explanatory variables were held constant, the average value of carbon emissions in Nigeria will not be significant. This implies that in the absence of productive activities, emission will reduce to the lowest possible, including becoming negative, because the available Carbon IV Oxide should have been used by vegetations. This may be a pointer to the fact that the industrial level of the country is so low. Also, the result indicates that out of all the independent variables employed, only ENU was statistically insignificant at the 5% level of significance. However, GDP, GDP^2, TOP, FDV, URB and POP were statistically significant at the 5% level of significance and indicates that they have a significant long run effect on carbon emissions in Nigeria. The results further indicate that GDP, TOP, FDV and URB have a negative effect on carbon emissions in Nigeria in the long run. This may be because the energy source does not produce higher emissions up to the requirement of the green environment. This implies that an increase in GDP, TOP, FDV and URB, will lead to a decrease in carbon emissions in Nigeria in the long run. On the other hand, GDP^2 and POP were discovered to have a significant positive long run effect on carbon emissions in Nigeria. This implies that an increase in GDP^2 and POP will lead to an increase in carbon emissions in Nigeria in the long run. It is worth noting that since the coefficient of GDP is negative and that of GDP^2 is positive, the inverted U-shape suggested by the EKC hypothesis is not valid in Nigeria during the study period. This indicates that carbon emissions continue to increase at higher level of output since adequate environmental considerations has not been put in place.

4.6.ARDL Error Correction Results

To examine the short run relationship between carbon emissions and economic growth in Nigeria, the study carried out an error correction examination, using the ARDL Error correction mechanism (ECM). The summary of the ARDL ECM output is presented in table 4.6;

Table 4.6: ARDL Error Correction Results

Dependent Variable: CE

Variable	*Coefficient*	*Standard Error*	***t-Statistic***	***Probability***
ΔGDP	-0.006	0.003	-1.803	0.109
ΔGDP^2	0.002	0.000	6.166	0.000
ΔTOP	-0.003	0.001	-4.239	0.003
ΔENU	0.002	0.000	5.914	0.000
ΔFDV	-0.008	0.002	-4.435	0.002
ΔURB	-0.132	0.032	-4.133	0.003
ΔPOP	-0.030	0.155	-0.194	0.851
ECM(-1)	-0.762	0.082	-9.270	0.000

Durbin-Watson stat = 2.06, R-squared = 0.90, Adjusted R-squared = 0.95,

Source: Researcher's Compilation (2023)

From table 4.6 above, the ECM output is summarized with CE being the dependent variable and GDP, GDP^2, TOP, ENU, FDV, URB and POP being the explanatory variables in the model. At the 5% level of statistical significance, the Error Correction Coefficient (ECM (-1)) was correctly signed (that is, it had a negative value), and it was significant statistically. This lends credence to the evidence that there is a long-run link between the variables, and it also suggests that in the case of any output disequilibrium, the system will self-correct from the short-run to the long-run equilibrium at a rate that is around 76% per year. Similarly, Table 4.6 provides more evidence that the dynamic model is a good fit. This is due to the fact that the R^2 value, which was discovered to be 0.90%, indicated that the control variables were responsible for explaining 95 percent of the variation in CE. The model has a stochastic disturbance term, which is responsible for the remaining 5 percent of the variance. The fact that the model does not exhibit first-order autocorrelation is demonstrated by the model's Durbin Watson statistic, which is 2.06, which is approximately 2. According to Gujaraji (2009), an estimated regression model will generate false results if the R^2 value is higher than the Durbin Watson Statistic and if the R^2 value is greater than the Durbin Watson Statistic. Because of this, the fact that the Durbin Watson (DW) value of 2.06 is higher than the R^2 value of 0.95 demonstrates that our findings are not erroneous and that the model is free of any autocorrelation.

Taking into consideration the statistical significance of the model, the coefficient of GDP was wrongly signed (that is, it was negative), which meant that it failed to conform to the a-priori expectation. Also, GDP was discovered to be statistically insignificant as depicted by its probability value of 0.109 which is greater than the threshold significance value of 5%. In light of this, it is established that GDP has no significant short run effect on carbon emissions in Nigeria. This indicates that variations in carbon emissions in Nigeria, in the short run are not explained by variations in GDP. Conversely, GDP^2 was found to be positive and statistically significant at the threshold significant level of 5%. This indicates that a GDP^2 conforms to the already established a-priori expectations based on theoretical underpinnings. The findings also support the view that a percent increase in GDP^2 will lead to a 0.002 percent increase in carbon emissions in the short run in Nigeria. This finding has therefore established the fact that GDP^2 is significant at explaining variations in carbon emissions in the short run in Nigeria and can be used for making predictions regarding future changes in short run values of carbon emissions in the country.

Aside from the above, other interesting discoveries was the fact that TOP was discovered to be negative and statistically significant at the 5% threshold level. Although, TOP failed to conform to the already stated a-priori expectations, its value indicates an inverse interplay between TOP and carbon emissions in the short run in the country. This implies that a percent increase in TOP will result in a 0.002 percent decrease in carbon emissions in the short run in the country. This finding supports the view that predictions can be made in the short run values of carbon emissions in Nigeria through utilising TOP. Aside from that, ENU was also discovered to be significant at the 5% threshold significance level but positive indicating a positive short run relationship between ENU and carbon emissions in Nigeria. This implies that a percent increase in ENU will result in a 0.002 percent increase in the short run value of carbon emissions in Nigeria. This also implies that ENU is a significant variable impacting the short run variations of carbon emissions in the country.

Similarly, FDV was found to be negative but statistically significant at the 5% level of significance. This indicates that a percent increase in FDV will result in a 0.008 percent decrease in carbon emissions in the short run in Nigeria. This finding also depicts FDV to be a significant variable impacting short run values of carbon emissions in the country. URB was also found to be negative and statistically significant at the threshold significance level of 5%. This implies that a percent increase in URB will result in a 0.13 percent decrease in carbon emissions in the short run in Nigeria. Lastly, POP was discovered to be negative and statistically insignificant at the threshold level of 5%. The probability value of POP (0.85) was greater than the 5% level and such POP does not explain short run variations in carbon emissions in the country.

4.7. Granger Causality Test

The Clive Granger causality test is employed in this section to investigate whether economic growth Granger causes carbon emissions. And if the direction is unidirectional or bidirectional. Carbon emission is taken as the dependent variable, while economic growth variables are taken as the independent variables. The summary of the causality test is demonstrated below.

Table 4.8: Granger Causality Test Results

Direction of Causality	*No. of Obs.*	*F-Value*	*Prob.*	*Decision*
GDP does not Granger Cause CE	30	3.474	0.044*	Reject Ho
CE does not Granger Cause GDP	30	8.194	0.003*	Reject Ho

Note: * indicates significant at 5% level
Source: Researcher's Computation (2023)

The result in Table 4.8 shows the nature of the relationship existing between the variables used in the study. From the results, a bidirectional causal relationship was found to exist between carbon emissions (CE) and GDP for the period of study. This shows that carbon emission Granger causes GDP and also GDP Granger causes carbon emission during the period of study. The finding also discovered that there was no significant causal relationship between GDP^2 and CE in Nigeria.

4.9. Discussion of Finding

This study has effectively evaluated the effect of economic growth on carbon emissions in Nigeria. The study has shown that GDP has a significant negative long run effect on carbon emissions in Nigeria. On the other hand, an insignificant relationship was discovered between GDP and carbon emissions in the short run. However, the fact that GDP has a negative long run effect on CE is surprising given that based on theoretical underpinnings, particularly, the EKC model, higher levels of economic growth is supposed to result in higher carbon emissions within the economy. Therefore, for any change in economic activities, it had a significant positive effect on CE and conforms to the a-priori expectations already established in the study. This finding corroborates that of Dogan & Seker (2016) and Pejovi´c *et al*. (2021) who have discovered similar discovery. The studies discovered that positive changes in GDP is associated with positive changes with carbon emissions. This actually leads to a greater release of carbon in the economy.

Also, as the economy grows, more and more individuals will be able to afford quality education and would earn above average income. Studies have discovered the link between increase in economic growth and increase in standard of living of individuals (Alaganthiran & Anaba, 2022; Bouznit & Pablo-Romero, 2016; Lešáková & Dobeš, 2018; Pejovi´c *et al*., 2021; Sisodia et al., 2023; Wang *et al*., 2022). This implies a growing economy will experience rising income and such will indicate that more people will be able to afford to buy cars as compared to before and use more mechanized equipment amongst others. Such will lead to a considerable increase in CE in the economy. However, the EKC model also revealed that as time goes on, there will be inverse interplay between economic growth and CE, as higher levels of economic growth will reduce carbon emissions. However, this only occurs in the long run period and is consistent with the discovery of the long run negative effect of GDP on carbon emissions as discovered in the study.

The short run aspect of the study also revealed that GDP has no significant effect on CE in the short run. However, GDP^2 was found to have a significant positive effect on CE in the short run. This is an indication that in the short run changes in GDP^2 will bring about positive changes in CE. This finding aligns with the view of Olubusoye and Musa (2020) noting that as the economy becomes more productive in the short run, than expected a higher level of emissions will be expected which will entail rising emissions coming from rising economic activities. Also, Okedina *et al*. (2021) contend that while economic growth affects the short run total amount of carbon emissions, in turn, the amount of carbon emissions reflects the degree of economic development, there is a mutual two-way causal relationship between CE and economic growth as discovered in the study, and actively developing a green economy can effectively reduce carbon emissions.

5. Summary, Conclusion and Recommendation

5.1. Summary

The study looked at the effect of economic growth on carbon emissions in Nigeria over a 32-year period, from 1990 to 2021, for which annual time series data on the relevant variables were used. The study had four specific objectives: to explore the existing literature on the link between CO_2 and economic growth; to evaluate the short and long run interplay between CO_2 and economic growth in Nigeria; to investigate the causal relationship between CO_2 and economic growth in Nigeria and to make practical recommendations based on the study's findings. The study adopted two models, the first model, being the econometric model was employed to address the second objective, while the second model, being the Clive Granger Causality test model was employed to address the third objective. Each of these objectives were analyzed using distinct estimation techniques which were clearly and separately reported in the study. From 1990 through 2021, the analysis used time series data from the World Development Indicators (WDI) carbon emission (CE), gross domestic product (GDP), trade openness (TOP), energy use (ENU), financial development (FDV), urbanization (URB) and annual population growth (POP). The ARDL bounds test for co-integration indicated that carbon emission and economic growth in Nigeria have a long-run relationship. Similarly, the long-run coefficients indicated that aside ENU all independent variables have a significant effect on carbon emissions in the long run. However, GDP^2 and POP have positive effect on CE, while GDP, TOP, FDV and URB have negative effect on CE in the long run. On the other hand, the ARDL Error Correction results revealed that GDP^2, TOP, ENU, FDV and URB have significant effect on CE in the short run. However, GDP and POP did not significantly impact CE in the short run. It was also revealed that while GDP^2 and ENU have positive effect on CE, TOP, FDV and URB have negative effect on CE in the short run. Furthermore, the ECM coefficient was negative and statistically significant, meaning that in the event of any economic disequilibrium, the system will correct itself in the short run at a rate of 76 percent every quarter, eventually attaining long-term equilibrium. For model two, the Granger Causality result indicated that a significant bidirectional relationship exists between carbon emission and economic growth in Nigeria. This implies that carbon emission Granger causes growth and economic growth also Granger causes carbon emission in Nigeria.

5.2. Conclusion

This study has been successful in examining key issues relating to the effect of economic growth on carbon emissions in Nigeria. The study has shown that against previous beliefs and arguments, economic growth can positively and negatively impact carbon emissions. The study has shown that to be true for the Nigerian situation in which there is both a positive short run and long run of economic growth on carbon emissions. This indicates that while the quest for growth is an important consideration for an economy, there should be an understanding that such goal could have negative impact on the economy through leading to higher levels of emissions. The study, therefore, concludes that carbon emission may not be entirely bad to a nation and in some cases can positively contribute to a nation's growth.

The study further concludes that for a growing nation such as Nigeria it may be challenging effectively curtailing carbon emission. This is based on the fact that as more industries are being developed, incomes will keep rising and more households will be able to afford cars and other good things of life they were once unable to afford. This will ensure that emissions will keep rising until the nation has achieved certain growth potential before it will be able to effectively divert to cleaner energies. There is also the concern of monitoring carbon emissions by regulatory bodies in the nation. Being a less-developed country, Nigeria lacks requisite regulatory potential and monitoring capacity to ensure requisite compliance with carbon emission policies and standards. Therefore, given these issues, there is more likelihood for carbon emission to rise in the future. Nonetheless, the carbon emission levels in Nigeria is still far below that of other advanced countries such as the US and China, given that the country is yet to reach the level of development in those countries. The study further concludes that carbon emission causes growth in Nigeria given that there has been proliferation in economic activities from increases in carbon emission. However, economic growth is also observed to cause carbon emission as increased growth comes with greater level of production and manufacturing activities which ensure that emissions take place.

Recommendation

Based on the insightful discoveries of the study, there is need to offer practical recommendations for requisite practices relating to carbon emissions in the economy. Therefore, the following recommendations are proffered.

Given the discovery of the fact that economic growth significantly impacts carbon emissions in Nigeria, the study recommends that a balance be established between carbon emission and economic growth in Nigeria. This can be done by ensuring that unproductive activities that results in carbon emission are curtailed.

Most often, unproductive activities are the ones that results in greater carbon emission than productive activities. Therefore, concerted efforts should be developed by the government and other relevant stakeholders in ensuring that the requisite standards are set for carbon emission.

While economic growth always brings about increase production, manufacturing, distribution and consumption that would lead to higher emissions, there could be ways of ensuring that emissions from these activities are effectively controlled. Therefore, it is recommended that concerted efforts be established by all relevant stakeholders at providing sensitization programmes, symposia, conferences, and seminars targeted at educating and informing the public about the need for ensuring that green energy utilization is fostered. More awareness of green energy will increase its adoption, particularly, when people are aware of its benefits for themselves and the society at large.

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