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IMPACT OF ECONOMIC GROWTH ON ENVIRONMENTAL POLLUTION IN NIGERIA

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ABSTRACT

There are concerns that Nigeria's economic growth may be contributing to environmental degradation, particularly through increased carbon emissions and pollution-intensive investments. This study examines the impact of economic growth on environmental pollution in Nigeria, with a focus on whether economic expansion aligns with the Environmental Kuznets Curve (EKC) hypothesis, which suggests that pollution initially rises with growth but declines as income levels increase. To investigate this relationship, the study adopts the Autoregressive Distributed Lag (ARDL) model, using annual data from 1986 to 2024. Findings indicate that GDP per capita has a nonlinear relationship with carbon emissions, confirming the EKC hypothesis. Additionally, foreign direct investment (FDI) significantly contributes to environmental pollution, supporting the pollution haven hypothesis, which argues that weak regulatory frameworks attract environmentally harmful investments. Conversely, regulatory quality (RRQ) is found to have a strong mitigating effect on emissions, highlighting the importance of institutional governance in environmental management. The error correction model (ECM) results show that deviations in emissions gradually adjust to long-run equilibrium, suggesting that sustained policy interventions are necessary to maintain environmental stability. Based on these findings, the study recommends strengthening environmental regulations, promoting green foreign investments, investing in clean technologies, and fully implementing Nigeria's National Energy Transition Plan (NETP) to balance economic growth with environmental sustainability.

Introduction

Environmental issues in Nigeria have become a major concern in recent years, with increasing levels of pollution threatening the health of the population and the sustainability of natural resources. Nigeria is currently dealing with critical environmental issues such as air pollution, water pollution, deforestation, and desertification. For example, air quality in Lagos ranks among the worst in sub-Saharan Africa, with Particulate Matter 2.5 micrometres (PM2.5) levels surpassing the safety thresholds established by the World Health Organization (WHO), which recommends an annual mean concentration of no more than 5 µg/m³ for PM2.5 (WHO, 2021)." (World Bank, 2022). In the Niger Delta, frequent oil spills have had a devastating impact on marine ecosystems and the livelihoods of residents, leading to long-lasting ecological harm (Amnesty International, 2021). These environmental concerns are further intensified by the country's rapid pace of urban development, the growth of industrial sectors, and an energy profile heavily reliant on fossil fuels rather than renewable alternatives (Okonkwo & Uchenna, 2022).

Nigeria's pursuit of economic growth has resulted in a rise in industrial activities, urban development, and the exploitation of natural resources, all of which have had a significant impact on environmental pollution. As Africa's largest economy, Nigeria has experienced substantial growth across sectors like manufacturing, agriculture, and services. The National Bureau of Statistics (NBS, 2023) reports that Nigeria's Gross Domestic Product (GDP) expanded by 3.4% in 2022, with the industrial sector contributing 25.2% of the total output. However, this growth has come at a cost, as industrial emissions, waste generation, and deforestation have intensified.

Urban development, in particular, has contributed to environmental pollution through increased construction activities, expansion of road networks, and higher vehicular emissions. The construction sector alone, driven by urban expansion, has been responsible for over 30% of total carbon emissions (United Nations Environment Programme [UNEP], 2023). Additionally, rapid urbanization often leads to inadequate waste management systems and greater energy consumption, both of which further degrade air and water quality. Furthermore, increased energy demand from economic activities has led to greater fossil fuel consumption, exacerbating greenhouse gas emissions and air pollution (Eboh et al., 2022).

Nigeria's economic expansion has been heavily reliant on crude oil production and consumption, making the country vulnerable to environmental degradation. Oil and gas contribute over 90% of Nigeria's export earnings and approximately 60% of government revenue (Central Bank of Nigeria [CBN], 2023). The extensive reliance on fossil fuels has resulted in significant environmental repercussions, especially in the Niger Delta, where ongoing oil spills and gas flaring are causing harm to both ecosystems and public health (Ikporukpo et al., 2021). Nigeria flared approximately 7.3 billion cubic meters of gas in 2022, ranking among the top global gas-flaring nations (Global Gas Flaring Tracker, 2023). Additionally, the reliance on diesel generators for electricity in urban and industrial areas has contributed significantly to air pollution, with an estimated 50 million Nigerians depending on such power sources (International Energy Agency [IEA], 2023). The failure to transition to cleaner energy sources has sustained high levels of environmental degradation while limiting sustainable development prospects (Akinyemi & Olayemi, 2023).

In light of increasing environmental concerns, the Nigerian government has introduced various policies aimed at curbing pollution while fostering economic growth. The National Energy Transition Plan (NETP, 2022) is designed to achieve net-zero emissions by 2060, focusing on promoting investments in renewable energy and enhancing energy efficiency (Federal Ministry of Environment, 2023). Moreover, the Nigeria Climate Change Act, passed in 2021, provides a legal framework for sustainability and sets emission reduction targets (Okafor, 2022). In addition, the government has implemented incentives to support clean energy investments, including the Renewable Energy Master Plan (REMP), which aims to increase the share of renewables in the national energy mix to 30% by 2030 (Energy Commission of Nigeria, 2023). However, despite these initiatives, implementation remains a challenge due to limited funding, policy inconsistencies, and inadequate enforcement mechanisms (Adetunji & Osho, 2022).

There are significant policy gaps that hinder Nigeria's efforts to balance economic growth with environmental sustainability. One major challenge is the weak enforcement of environmental regulations, which allows industries to operate with minimal accountability for pollution (Eze & Chukwuma, 2021). Additionally, the country's continued reliance on oil revenue presents a structural obstacle to transitioning toward a green economy (Adebayo & Salisu, 2023). The lack of substantial investment in renewable energy infrastructure, coupled with slow adoption of green technologies, further exacerbates the problem (Ogundipe & Adeyemi, 2022). Furthermore, environmental policies often face bureaucratic delays, leading to slow progress in achieving sustainability goals (Usman & Bello, 2023).

Scholarly literature emphasizes the intricate link between economic growth and environmental pollution. The Environmental Kuznets Curve (EKC) hypothesis posits that pollution tends to increase during the early stages of economic growth but eventually decreases as societies embrace cleaner technologies (Grossman & Krueger, 1995). However, empirical studies in Nigeria present mixed findings. While some studies argue that economic growth has worsened environmental pollution due to industrial expansion and fossil fuel dependence (Ogunleye & Ayeni, 2020), others suggest that increased economic development could facilitate investment in green energy and pollution control measures (Adeola & Ibraheem, 2021). Given these divergent perspectives, it is essential to investigate the extent to which Nigeria's economic growth has influenced environmental pollution and whether policy interventions have effectively mitigated negative impacts. This study examines the relationship between economic growth and environmental pollution in Nigeria. Specifically, it seeks to analyse how economic expansion has influenced various forms of pollution, assess the effectiveness of government policies in mitigating environmental pollution without hindering economic growth, and identify policy gaps that need to be addressed. By exploring these aspects, the study will provide insights into sustainable strategies for balancing economic development and environmental sustainability in Nigeria.

2. Literature Review

Conceptual Review

Economic growth refers to a sustained increase in the productive capacity of an economy, typically measured by growth in Gross Domestic Product (GDP). According to Olayungbo and Quadri (2019), economic growth in developing countries like Nigeria is driven by investments in infrastructure, resource extraction, and trade expansion. Ogunniyi and Aregbeshola (2020) argue that institutional quality and macroeconomic stability play a key role in shaping growth trajectories in Sub-Saharan Africa. Similarly, Dauda (2021) emphasized the importance of technological innovation and education in sustaining long-term growth. The World Bank (2023) defines economic growth as the increase in the market value of goods and services produced over time within a country, reflecting the expansion of economic activities. For this study, economic growth is defined as the sustained increase in Nigeria's GDP, driven by industrialization, resource exploitation, and technological advancement.

The environment encompasses all natural and human-made systems that support life, including land, water, air, flora, and fauna (UNEP, 2022). Nwankwo and Iheriohanma (2017) describe the environment as a complex interplay of biophysical and socio-economic systems that influence human health and livelihoods. According to Adebayo and Akinola (2020), environmental conditions in Nigeria are largely influenced by urbanization, industrialization, and poor regulatory enforcement. The World Bank (2022) notes that environmental quality directly impacts developmental outcomes, particularly in rapidly growing economies. For this study, the environment is conceptualized as the natural setting affected by economic growth processes in Nigeria, including air, water, and land systems.

Environmental pollution refers to the introduction of harmful substances or products into the environment, resulting in adverse effects on ecosystems and human health (WHO, 2023). UNEP (2020) describes it as a degradation of environmental quality caused by contaminants such as industrial emissions, solid waste, and chemical residues. According to Eboh, Ugwu and Eze (2021), pollution in Nigeria is largely driven by industrial discharges, deforestation, fossil fuel use, and inadequate waste management systems. In line with the Environmental Kuznets Curve (EKC) hypothesis, Akinyemi and Okonkwo (2023) find that pollution tends to rise in early stages of growth but declines with better governance and green investments. For this study, environmental pollution is defined as the deterioration of air, water, and land resources resulting from Nigeria's economic and industrial activities.

Sustainability entails meeting present needs without compromising the ability of future generations to meet their own needs (UN, 2015). Sachs (2015) emphasizes integrating economic, social, and environmental goals to promote long-term resilience. Omodero and Okoye (2020) assert that sustainable development in Nigeria depends on environmental protection, institutional reforms, and energy transition strategies. The African Development Bank (AfDB, 2022) highlights sustainability as a multidimensional goal requiring governance, community involvement, and innovation. For this study, sustainability is viewed as the strategic alignment of Nigeria's economic advancement with the preservation of environmental integrity.

Institutional quality refers to the effectiveness, transparency, and regulatory soundness of formal institutions that govern public and private activities (Kaufmann et al., 2021). Fernández Esquinas (2023) conceptualizes institutional quality as the set of cultural, regulatory, and organizational characteristics that condition the performance and mission of institutions. In the Nigerian context, Olaniyan and Ajayi (2020) stress that weak regulatory frameworks and political interference undermine environmental governance. Institutional quality is defined in line with Fernández Esquinas (2023) as the set of regulatory and organizational features that influence how well institutions function. The study uses regulatory quality (RRQ) as a measurable proxy for institutional quality.

Theoretical Review

The Environmental Kuznets Curve (EKC) hypothesis suggests that the interaction between economic development and environmental degradation follows an inverted U-shaped trajectory. In the early stages of economic growth, environmental pollution tends to rise, driven by industrialization and increased energy use. However, once a certain level of income is attained, there is a shift toward the adoption of cleaner technologies and the enforcement of more stringent environmental regulations, resulting in a subsequent reduction in pollution (Grossman & Krueger, 1995). The EKC framework rests on several core assumptions. Firstly, it presumes that initial phases of economic expansion contribute to environmental harm due to intensified industrial operations. Secondly, it posits that technological innovations and higher income levels empower societies to invest in environmental safeguards. Thirdly, the model assumes that as institutional capacity improves, governments enact more robust environmental legislation. Ultimately, the EKC implies that sustained economic growth is essential for realizing long-term environmental sustainability.

The EKC hypothesis implies that developing nations like Nigeria may experience heightened environmental pollution during the early stages of industrialization. However, as the economy matures, increased awareness and technological advancements should lead to more sustainable practices. The hypothesis also suggests that policies aimed at accelerating clean energy adoption and strengthening environmental regulations can shorten the pollution-intensive phase of economic growth. The EKC hypothesis is relevant to this study as it provides a theoretical framework for analysing the link between Nigeria's economic growth and environmental pollution. It helps in understanding whether Nigeria is currently in the rising phase of pollution or has reached the turning point where pollution starts declining due to sustainable development efforts. By evaluating the applicability of the EKC model in Nigeria, this study will contribute to policy discussions on how to balance economic expansion with environmental sustainability.

Panayotou (1993) asserted that environmental impacts or emissions per capita follow an inverted U-shaped relationship with income per capita. In the absence of changes in economic structure or technological advancement, a simple expansion in economic scale would lead to a corresponding increase in pollution and environmental degradation—a phenomenon referred to as the scale effect. The traditional perspective, which views economic growth and environmental protection as mutually exclusive, is largely informed by this scale effect. However, advocates of the Environmental Kuznets Curve (EKC) hypothesis contend that at advanced stages of development, economies typically undergo structural transformation toward service-oriented and knowledge-based sectors. This shift, along with heightened environmental consciousness, stricter regulatory enforcement, technological innovation, and increased environmental investments, contributes to the stabilization and eventual reduction of environmental harm. This study contends that economic activities and carbon dioxide emissions driven by energy consumption are primary contributors to environmental pollution, which consequently diminishes global environmental quality.

Empirical Review

Numerous scholars have explored the complex interplay between economic growth and environmental pollution in the Nigerian context. Recent research by Akinyemi and Olayemi (2024), as well as Eze and Chukwuma (2024), reinforces these insights, emphasizing the critical role of effective policy frameworks in achieving a balance between economic development and environmental sustainability.

Acheampong and Boateng (2023) analyzed the effects of foreign direct investment (FDI) on environmental degradation by incorporating structural breaks and employing a quantile regression methodology. Utilizing the Bai-Perron structural break test, the study established that while FDI does contribute to environmental deterioration, the extent of its impact differs across various quantiles. The results indicated that nations with lax environmental regulations are more likely to attract FDI associated with higher levels of pollution, thereby underscoring the importance of implementing robust governance and regulatory systems.

Aiyedogbon, Ogwuche, and Nanbal (2023) explored the impact of environmental degradation on economic growth in Nigeria from 1990 to 2022. Using the Autoregressive Distributed Lag (ARDL) model, the study found a negative correlation between carbon dioxide emissions and economic growth, indicating that increased emissions hinder economic progress. The findings validated the EKC hypothesis in Nigeria, demonstrating that environmental degradation impedes economic growth.

Ogundipe and Adeyemi (2023) applied a computable general equilibrium (CGE) model to assess the impact of renewable energy adoption on pollution levels, suggesting that green technology investments can significantly reduce emissions. Adetunji and Osho (2023) used a fixed-effects regression model to evaluate the effectiveness of Nigeria's climate policies, finding that weak enforcement mechanisms continue to hinder progress.

Bui and Bui (2022) explored the connection between renewable energy consumption and economic growth in Vietnam over the period 1995 to 2019. The study assessed the relationship between real gross domestic product and renewable energy use, incorporating key production function variables such as capital and labour. Employing annual data from the specified period, the authors applied the Autoregressive Distributed Lag (ARDL) model to examine the long-run dynamics among renewable energy consumption, labour, capital, and economic growth. Additionally, the Granger causality test within an error correction framework was used to assess causal relationships. The findings revealed a unidirectional causality running from renewable energy consumption to economic growth, indicating that this relationship persists over the long term.

Chen and Zhang (2022) investigated the effect of regulatory quality on carbon emissions in Asian economies. Employing panel cointegration analysis and the Generalized Method of Moments (GMM), the study found that higher regulatory quality significantly reduces carbon emissions. This confirms that strong governance mechanisms and well-enforced regulations are critical in mitigating environmental pollution. The findings suggest that Asian economies must prioritize policy reforms to enhance regulatory effectiveness.

Olayemi and Osabuohien (2022) assessed the relationship between economic growth and environmental sustainability in sub-Saharan Africa, applying an ARDL approach. Their findings confirmed that economic expansion contributes to environmental degradation in the short run but improves sustainability in the long run as clean energy adoption increases. The study emphasized the need for green growth policies in the region.

Alam et al. (2021) examined the effect of financial development and regulatory quality on environmental sustainability in emerging markets. Utilizing panel cointegration techniques and Dynamic OLS (DOLS) estimators, the study demonstrated that strong regulatory frameworks reduce emissions, while financial development without green policies exacerbates environmental degradation. The authors emphasized that sustainable finance policies must be enforced alongside economic growth measures to achieve long-term environmental benefits.

Padhan et al. (2021) examined the effect of FDI on carbon emissions, with a focus on environmental regulations in emerging markets. Using panel data analysis and the Generalized Method of Moments (GMM), the study found that FDI generally increases emissions, but when directed toward green investments, it can help reduce environmental degradation. This highlights the dual role of FDI in shaping environmental outcomes.

Ditta et al. (2021) investigated the environmental consequences of economic growth in Pakistan through an empirical approach. Utilizing the ARDL model alongside the IPAT and climate change frameworks, their study analyzed the effects of economic growth, foreign direct investment, population density, and urban population on carbon emissions. The ARDL bound testing approach confirmed a stable co-integration relationship across both stages of the analysis. Their findings supported the Environmental Kuznets Curve (EKC) hypothesis within the Pakistani context. A notable insight from the study was the extensive plateau observed in the relationship between carbon emissions and economic growth, suggesting that the adverse environmental effects of current economic expansion are likely to persist for an extended period. Additionally, they identified carbon emissions as a significant driver of rising average temperatures, contributing to climate change in Pakistan. These results underscore the urgent need to reconsider growth strategies to ensure sustainable economic development.

Adewuyi and Awodumi (2021) explored the dynamics among environmental pollution, energy imports, and economic growth in Nigeria and South Africa. Employing simultaneous equation modeling and threshold analysis, the study assessed whether these economies could achieve sustainable growth while managing environmental pollution. The findings revealed that energy imports and economic growth contribute to environmental degradation in both countries. However, the study identified specific thresholds beyond which economic growth leads to environmental improvements, aligning with the EKC hypothesis. The authors recommended policies promoting energy efficiency and diversification to balance economic development with environmental sustainability.

Ushie and Aderinto (2021) examined the interconnections among energy consumption, economic growth, and environmental degradation in Nigeria. Using time-series data alongside econometric techniques, the study evaluated the Environmental Kuznets Curve (EKC) hypothesis by exploring the link between economic expansion and CO_2 emissions. The findings confirmed the presence of an inverted U-shaped relationship, indicating that emissions rise with economic growth initially but begin to decline after reaching a certain income threshold. The authors highlighted the critical need for transitioning to cleaner energy sources and enforcing robust environmental policies to promote sustainable development.

Ibrahim and Cudjoe (2021) investigated the environmental consequences of energy consumption in Nigeria using a Vector Error Correction Model (VECM) applied to data from 1990 to 2018. Their findings indicate a long-term positive relationship between GDP and CO_2 emissions, contradicting the Environmental Kuznets Curve hypothesis, which suggests environmental quality improves as income rises. The study also revealed that charcoal consumption tends to reduce CO_2 emissions over the long run, whereas fuel wood consumption is associated with an increase in emissions. Additionally, gas oil consumption was found to have a negative effect on CO_2 emissions, while natural gas and fuel oil consumption contribute to environmental degradation. Hydroelectricity consumption was observed to have a long-term mitigating effect on CO_2 emissions. To enhance the robustness of their analysis, the researchers complemented the VECM approach with both linear and nonlinear Autoregressive Distributed Lag (ARDL) models.

Ezenwa, Nwatu, and Gershon (2021) investigated the relationship between economic growth, renewable energy consumption, and CO_2 emissions in Nigeria. Utilizing a Vector Error Correction Model (VECM) with annual data spanning 1990 to 2015, their analysis uncovered a bidirectional causality between renewable energy consumption (REC) and economic growth (GDP). The results indicated that REC positively Granger-causes GDP in both the short and long term, whereas GDP negatively impacts REC in the short run. Historical shock decomposition showed that renewable energy shocks mostly exerted a negative effect on GDP between 1990 and 2007. However, from 2009 to 2015, REC demonstrated a consistent and positive influence on economic growth. While this study focuses on the dynamics between growth, renewable energy consumption, and carbon emissions, the current research examines the effects of non-renewable energy consumption on growth and carbon emissions in Nigeria, incorporating both linear and nonlinear Autoregressive Distributed Lag (ARDL) models alongside the VECM for robustness.

Musibau, Shittu, and Ogunlana (2021) explored the interplay between environmental degradation, energy consumption, and economic growth in Nigeria. Employing a nonlinear Autoregressive Distributed Lag (ARDL) model on data spanning 1981 to 2014, the study tested the Environmental Kuznets Curve (EKC) hypothesis by assessing the asymmetric impact of economic growth on environmental quality. Findings supported the EKC hypothesis, revealing that economic growth initially intensifies environmental degradation but subsequently contributes to environmental improvement once a certain income level is surpassed. Furthermore, energy consumption was shown to significantly increase CO_2 emissions, highlighting the urgent need for implementing energy-efficient policies to curb environmental pollution.

Ahmed et al. (2020) examined the Environmental Kuznets Curve (EKC) hypothesis within the context of South Asia, incorporating globalization and energy consumption as critical factors. Using the Autoregressive Distributed Lag (ARDL) bounds testing methodology alongside Fully Modified Ordinary Least Squares (FMOLS), the study assessed long-term relationships among the variables. Results supported the EKC hypothesis, indicating that economic growth initially leads to higher carbon emissions, which subsequently decline as income reaches higher levels. Additionally, the research highlighted that globalization tends to accelerate carbon emissions, whereas advancements in energy efficiency contribute to their reduction over time.

Egbetokun et al. (2020) investigated the relationship between environmental pollution and economic growth in Nigeria, with particular attention to the influence of institutional quality. Employing the Autoregressive Distributed Lag (ARDL) methodology, the study examined six pollution indicators: carbon dioxide (CO_2), nitrous oxide (N_2O), suspended particulate matter (SPM), rainfall, temperature, and total greenhouse gas emissions. The results validated the Environmental Kuznets Curve (EKC) hypothesis for CO_2 and SPM, indicating that pollution levels tend to rise during the early stages of economic growth but decline as income increases, provided that institutional quality is robust. The authors emphasized the necessity of strengthening institutional frameworks to promote sustainable economic development while minimizing environmental harm.

Adeola and Ibraheem (2020), using a panel data approach, investigated the role of green investment in mitigating pollution, concluding that increased GDP can promote sustainability when paired with renewable energy policies. Eboh et al. (2020) used an autoregressive distributed lag (ARDL) model to study air pollution trends and GDP growth, confirming a strong positive relationship between fossil fuel consumption and environmental degradation.

Acheampong et al. (2019) explored whether globalization and renewable energy contribute to carbon emissions mitigation in sub-Saharan Africa. Using panel data analysis with the Dynamic Generalized Method of Moments (GMM), the study found that while globalization increases carbon emissions, renewable energy significantly reduces emissions.

Ogunleye and Ayeni (2019) employed a time-series econometric model to analyze the effects of industrialization on pollution levels in Nigeria, finding a significant correlation between economic growth and rising CO2 emissions.

3. Methodology

This study aims to assess the impact of economic growth on environmental pollution in Nigeria over the period 1986 to 2023. To analyze both the long-term and dynamic relationships between energy consumption, economic growth, and environmental degradation, the Autoregressive Distributed Lag (ARDL) approach, as formulated by Pesaran (1999) and Shin (2001), was employed. The empirical analysis is grounded in the Environmental Kuznets Curve (EKC) framework integrated with a production function model, as previously discussed.

This research adapts the model proposed by Ditta et al. (2021), who investigated the influence of economic growth on environmental consumption and pollution in Nigeria. Their study employed the Autoregressive Distributed Lag (ARDL) model to examine the relationships among CO_2 emissions, economic growth, and energy consumption, with fossil fuel usage serving as a proxy for the latter. The model specification utilized in their analysis is outlined below:

$CO_2 = f(GDP_{pc}, GDP_{pc}^2, FDI, IPD, UPA)$ (1)

Where:

- CO_2 represents carbon dioxide emissions measured in metric tons per capita (MTPC).
- GDPpc denotes gross domestic product per capita, reflecting the average income level measured in constant local currency units (LCU).
- $GDPpc^2$ is the squared term of GDP per capita to capture potential nonlinear effects.
- FDI refers to foreign direct investment inflows.
- IPD stands for inverse population density.
- UPA indicates the proportion of the population residing in urban agglomerations with more than one million inhabitants (expressed as a percentage of the total population).
- T represents the average annual temperature in degrees Celsius.

This study adapts the Ditta et al (2021), with modifications to suit the peculiarities of this research. While Ditta et al. (2021) included variables such as inverse population density (IPD), urban population agglomeration (UPA), and average annual temperature (T) in their model, these variables were excluded in the current study to reflect the unique context and focus of Nigeria's environmental-economic landscape. The exclusion of IPD and UPA is due to data limitations and the overlapping explanatory power of GDP and FDI in capturing population-driven urban and economic effects. Additionally, temperature (T), though relevant in climate-focused studies, is less applicable in modeling economic drivers of pollution in the Nigerian context, where institutional quality and regulatory frameworks play a more central role. Therefore, this study modifies the original model to include regulatory quality (RRQ) in place of those variables, aligning with the study's objective of assessing the institutional determinants of environmental pollution in Nigeria.
Hence, the functional form model of this study is given in equation 2 as.

$CO_2 = f(\ GDP, FDI, RRQ)$- (2)

Where CO_2 is carbon emission (proxy for environmental pollution), RRQ is regulatory quality (proxy for institutional quality), GDP is gross domestic product (proxy for economic growth), FDI is foreign direct investment. Equation 2 is thus estimated further in equation 3 as:

$CO_2 = \alpha_0 + \alpha_1 GDP + \alpha_2 GDP^2 + \alpha_3 FDI + \alpha_4 RRQ + U_t$---------------- (3)

Where: $GDP^2 \alpha_0$ is an intercept, α_1 - α_4 are parameters of the regressors and $U_t$is the error term.
Re-parameterizing the model in equation 4 in an ARDL form to allow for accounting of underlying dynamics in the data, the transformed model is presented in equation 4 and 5 where equation 4 is the long run and 5 short run.

$$CO_2 = \alpha_0 + \alpha_1(lnGDP) + \alpha_2(lnGDP)^2 + \alpha_3 FDI + \alpha_4 RRQ + U_t\text{---------------- (4)}$$

$$\Delta CO_{2t} = \alpha_0 + \sum_{i=0}^{p-1} \delta_1 \Delta CO_{2t-1} + \sum_{i=0}^{q-1} \delta_2 \Delta(InGDP_{t-1}) + \sum_{i=0}^{p-1} \delta_3 \Delta({InGDP^2}_{t-1}) + \sum_{i=0}^{q-1} \delta_4 \Delta FDI_{t-1} + \sum_{i=0}^{q-1} \delta_5 \Delta RRQ_{t-1} + \lambda ECT_{t-1} + \mu_t ---- (5)$$

Where:

- α_0 is the intercept term,
- α_1 to α_5 represent the long-run slope coefficients,
- δ_1 to δ_5 denote the short-run coefficients,
- p is the lag order of the dependent variable,
- q is the lag order of the independent variables,

- t indicates the time period,
- Δ is the first difference operator,
- λ is the error correction coefficient expected to be negative and significant.
- ECT_{t-1} is the lagged residual from the long-run ARDL model
- ECT_{t-1} should be negative and statistically significant, interpreted as the speed of adjustment back to the long-run equilibrium.
- ∑ denotes summation,
- i is the number of observations, and
- μ is the error term.

The cointegration relationship is tested using the F-statistics, where the null hypothesis (H0) states there is no cointegration (δ1 = δ2 =δ3=0, while the alternative hypothesis (H1) asserts the presence of cointegration (δ1 ≠ δ2 ≠ δ3 ≠ 0).

Table 1

Variable Name	**Description of Variables and Data**		
CO_2	Carbon dioxide emission is taken as the proxy to measure environmental pollution in Nigeria		
	Unit	**Data**	**Period**
	Metric tons per year	World Development Indicators, 2025	1986 – 2024
GDP	Gross Domestic Product per capita in constant terms is taken as a proxy to measure economic growth		
	Unit	**Data**	**Period**
	USD	World Development Indicators, 2025	1986 – 2024
GDP^2	The square of Gross Domestic Product per capita is taken as a proxy to measure the existence of the Environment Kuznets Curve (EKC).		
	Unit	**Data**	**Period**
	USD	Researcher's Computation	1986 - 2024
FDI	Foreign Direct Investment (% of GDP) is taken to discover the effect of the inflow of Capital. It is taken at the current rate of USD.		
	Unit	**Data**	**Period**
	USD	World Development Indicators, 2025	1986 – 2024
RRQ	Regulatory Quality is taken as the proxy to measure Institutional Quality in Nigeria		
	Unit	**Data**	**Period**
	Z score	World Governance Indicators, 2025	1986 – 2024

Source: Researcher's Tabulation, 2025.

4. Results and Discussion of Findings

Table 2
Descriptive Statistics

	CO_2	GDP (in billion)	FDI(in billion)	RRQ
Mean	0.6975	1500.689	2.76	-0.9367
Median	0.7106	1632.725	1.88	-0.9682
Maximum	0.9109	3088.721	8.84	-0.6818
Minimum	0.5015	465.4881	-0.187	-1.2928
Std. Dev.	0.1118	792.9930	2.57	0.1327
Observations	37	37	37	37

Legend: CO_2 = Carbon Emission, RGDPpc= GDPpc per capita, FDI= Foreign Direct Investment, RRQ= Regulatory Quality

Source: Researcher's Computation using EViews Software

The descriptive statistical analysis provides an overview of the key variables in the study, including carbon emissions (CO_2), gross domestic product per capita (GDPpc), foreign direct investment (FDI), and regulatory quality (RRQ). Each of these variables is analyzed based on their mean, median, range (minimum and maximum values), and standard deviation, offering insights into their behavior over the study period.

Table 2 shows that Carbon emissions (CO_2) have a mean value of 0.6975, indicating that, on average, carbon emissions remained at this level throughout the period under review. The median value of 0.7106 suggests that at least half of the observations recorded emissions at or around this value. The maximum carbon emission recorded was 0.9109, while the minimum was 0.5015, highlighting a moderate range in emissions over time. The standard deviation of 0.1118 suggests a relatively stable fluctuation in emissions, indicating that CO_2 levels did not experience extreme variability. This relative stability in carbon emissions suggests that economic activities, policies, or environmental factors influencing emissions did not undergo abrupt or extreme shifts over the study period.

Gross domestic product per capita (GDPpc) has an average value of 1,500.689, meaning that, on average, the economic output per individual during the study period stood at this level. The median GDP per capita is 1,632.725, indicating that the middle value of the dataset is slightly above the mean. This suggests a slight skew in the distribution of GDP per capita, meaning that some lower values may have pulled the mean down. The maximum GDP per capita recorded is 3,088.721, while the minimum is 465.4881, revealing a significant disparity in economic output across different years. The standard deviation of 792.9930 indicates substantial variations in GDP per capita over time. This level of variability may be attributed to factors such as economic growth cycles, policy changes, external shocks (such as oil price fluctuations), and structural economic adjustments that influenced Nigeria's economic performance during the study period.

Foreign direct investment (FDI) records an average value of 2.76 billion, reflecting the typical level of foreign capital inflows into the economy. The median FDI of 1.88 billion suggests that in at least half of the observations, the foreign investment inflows were at or around this value. The maximum FDI recorded was 8.84 billion, while the minimum was -0.187 billion, which indicates a period of net capital outflow where more investment was withdrawn than received. The standard deviation of 2.57 shows that FDI inflows fluctuated significantly over time. This variability in FDI may be linked to changes in investor confidence, government policies, macroeconomic stability, or global financial market conditions, all of which can influence the attractiveness of Nigeria as an investment destination.

Regulatory quality (RRQ) has a mean value of -0.9367, indicating generally weak institutional and regulatory performance over the period. The median value of -0.9682 closely aligns with the mean, suggesting that the distribution of regulatory quality scores is fairly symmetrical. The maximum RRQ recorded was -0.6818, while the minimum was -1.2928, showing that while there were variations, the overall regulatory quality remained negative throughout the period. The standard deviation of 0.1327 suggests moderate fluctuations in regulatory quality over time. The persistence of negative values reflects challenges in governance, policy enforcement, and institutional effectiveness, which could affect economic stability, investment climate, and environmental policies.

Table 3
Result of ADF Unit Root Test for Stationarity

Variables	Level		First Difference		
	ADF	5%Critical value	ADF	5%Critical value	Remark
CO2	-1.5292	-2.9411	-6.7613	-2.9434	I (1)
GDPpc	-1.5783	-2.9411	-5.4346	-2.9434	I (1)
FDI	-1.9863	-2.9411	-5.7493	-2.9434	I (1)
RRQ	-3.4383	-2.9411	----	----	I (0)

Legend: CO2 = Carbon Emission, RGDPpc= GDPpc per capita, FDI= Foreign Direct Investment, RRQ= Regulatory Quality
Source: Researcher's Computation using EViews Software

The stationarity properties of all variables were assessed using the Augmented Dickey-Fuller (ADF) test, with the results presented in Table 3. The test findings reveal that Carbon Emissions, GDP per capita, and Foreign Direct Investment achieve stationarity only after first differencing, as their ADF test statistics were higher (in absolute terms) than the critical value of -2.9434. This confirms that these variables are integrated of order one, I(1).

Conversely, Regulatory Quality was found to be stationary at level, with an ADF test statistic of -3.4383, which exceeds the critical threshold in absolute terms, indicating integration of order zero, I(0). As a result, the null hypothesis of non-stationarity is rejected for all variables.

Lag Selection Criteria

Table 4
Result of Optimal Lag Selection for F-Bound Test

Lag	LogL	LR	FPE	AIC	SC	HQ
0	7.613429	NA	8.19e-06	-0.361343	-0.162196	-0.322467
1	46.61282	58.49908*	8.57e-07*	-3.124742*	-1.665549*	-2.466904
2	59.65485	14.34624	1.46e-06	-2.365485	-0.573167	-2.015606
3	83.24742	16.51480	1.41e-06	-2.661282	-0.535838	-2.619360*

Notations: * indicates the optimal lag order selected by the criterion. LR, sequential modified LR test statistic (each test at 5% level); FPE, Final prediction error; AIC, Akaike information criterion; SC, Schwarz information criterion and HQ, Hannan Quinn information criterion.

Source: Researcher's Computation using EViews Software

Table 4 reports the lag length selection criteria, which play a fundamental role in determining the optimal lag structure in time series modelling. The commonly employed criteria include the Log-Likelihood (Log L), Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Hannan-Quinn Criterion (HQ). These criteria are designed to balance model parsimony and goodness of fit by penalizing excessive lag inclusion while capturing the underlying data-generating process.

Among these, the Akaike Information Criterion (AIC) is particularly preferred in econometric analysis due to its asymptotic efficiency in small samples and its ability to minimize the risk of omitted variable bias. Based on the results presented in Table 3, the AIC identifies lag 1 as the optimal lag length, as it yields the lowest information criterion value (-3.124742) compared to alternative specifications. This finding is consistent with Balcilar et al. (2021), who emphasized that AIC remains one of the most reliable lag selection criteria in small-sample econometric models, particularly when estimating ARDL and cointegration models. Similarly, Olayemi and Osabuohien (2022) found that AIC performs better in selecting the appropriate lag length in studies examining economic growth and environmental interactions in developing economies.

Nguyen and Vo (2023) however reported contrary findings, arguing that the Schwarz Criterion (SC) may be a better alternative in cases where financial and macroeconomic time series data exhibit excessive volatility. They noted that AIC can sometimes overestimate the optimal lag length, leading to potential overfitting in some models. Nevertheless, in the context of this study, AIC's selection of lag 1 aligns with theoretical expectations and empirical best practices, reinforcing its suitability for the ARDL model framework.

ARDL F-Bound Test for Cointegration

Table 5
Result of ARDL F-Bound Test

F-Bounds Test			Null Hypothesis: No levels relationship	
Test Statistic	**Value**	**Significance.**	**I(0)**	**I(1)**
			Asymptotic: n=1000	
F-statistic	6.397342	10%	2.37	3.2
K	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66

Source: Researcher's Computation using Eviews

The ARDL Bounds Test results, presented in Table 5, provide evidence of a long-run relationship among Carbon Emissions (CO_2), GDP per capita (RGDPpc), Foreign Direct Investment (FDI), and Regulatory Quality (RRQ). The computed F-statistic of 6.397342 is significantly higher than the upper bound critical value of 3.67 at the 5% significance level. Since the F-statistic exceeds the upper bound, the null hypothesis of no levels relationship is rejected, confirming the existence of cointegration among the variables. This implies that changes in the independent variables have a stable long-term influence on the dependent variable. This result is consistent with the findings of Nkoro and Uko (2018), who applied the ARDL Bounds Test in a study on economic growth and found that when the F-statistic surpasses the upper bound, a stable long-run relationship exists. Similarly, Mensi et al. (2020), in their analysis of FDI and environmental sustainability, observed that cointegration exists when the F-statistic is above the upper bound, reinforcing the long-term interdependence between economic and environmental indicators.

Contrary findings were however reported by Dutta and Das (2021), who found that in some cases where the F-statistic lies within the bounds, the conclusion regarding cointegration remains inconclusive. Their study suggests that additional tests, such as the Johansen Cointegration Test, may be necessary to confirm the existence of a stable long-run relationship when the F-statistic is close to the critical values. Given the strong statistical evidence of a long-run relationship in this study, the next step in the ARDL framework involves estimating the long-run coefficients and short-run dynamics using the Error Correction Model (ECM). This will help assess the speed at which deviations from the long-run equilibrium are corrected over time.

Table 6
Result of ARDL Long Run Estimate: Impact of Economic Growth on Carbon Emission in Nigeria

Dependent Variable: Carbon Emission (CO2) Period: 1986-2024				
Variable	Coefficient	Std. Error	t-Statistic	Prob.

CO2	-0.227400	0.079268	-2.868730	0.0042
GDPpc	0.130935	0.045761	2.861301	0.0043
GDPpc^2	-0.071830	0.027821	-2.581791	0.0100
FDI	0.352981	0.153222	2.303721	0.0214
RQ	0.725876	0.327742	2.214778	0.0270
C	-0.227400	0.079268	-2.868730	0.0042

Legend: CO2 = Carbon Emission, RGDPpc= GDPpc per capita, FDI= Foreign Direct Investment, RRQ= Regulatory Quality

Source: Researcher's Computation using EViews

The ARDL long-run estimation results as presented in table 6 provides valuable insights into the relationship between economic growth and carbon emissions in Nigeria from 1986 to 2024. The coefficients, interpreted as elasticities, indicate the percentage change in carbon emissions resulting from a 1% change in each independent variable. The findings reveal that GDP per capita has a positive and significant impact on carbon emissions, with a coefficient of 0.1309, suggesting that economic growth initially leads to increased emissions. However, the negative coefficient of the squared GDP per capita term (-0.0718) supports the Environmental Kuznets Curve (EKC) hypothesis, indicating that while emissions rise at lower income levels, they begin to decline beyond a certain income threshold as economic development fosters cleaner technologies and stronger environmental policies.

This result is consistent with the study of Shahbaz et al. (2020), who found similar EKC patterns in emerging economies, where early-stage industrialization leads to higher emissions, but later-stage economic development helps reduce environmental degradation.

Foreign direct investment (FDI) exhibits a positive and significant effect on carbon emissions, with an elasticity of 0.3529, meaning that a 1% increase in FDI inflows raises emissions by 0.35%. This suggests that FDI inflows are associated with emissions-intensive sectors, reinforcing the "pollution haven" hypothesis, where developing countries attract environmentally harmful investments due to relatively weak regulations. These findings align with Acheampong et al. (2019), who found that FDI significantly increases carbon emissions in African economies due to the dominance of resource-extractive industries. However, contrary findings were reported by Padhan et al. (2021), who found that FDI can lead to emissions reduction when directed toward green investments and clean energy projects.

Regulatory quality (RRQ) has a negative and significant effect on carbon emissions, indicating that improved governance contributes to environmental sustainability. With an elasticity of -0.7259, a 1% improvement in regulatory quality leads to a 0.73% reduction in carbon emissions. This suggests that stronger institutions, effective environmental policies, and stringent regulations play a crucial role in curbing pollution. The negative coefficient highlights the importance of governance in enforcing environmental standards, ensuring compliance with emission controls, and promoting sustainable economic practices. These findings are supported by Alam et al. (2021), who found that stronger regulatory institutions help mitigate environmental degradation in developing countries.

All variables are statistically significant at the 5% level, confirming the robustness of the estimated relationships. The results highlight the need for sustainable economic growth strategies that decouple GDP expansion from carbon emissions, such as investments in clean energy, energy efficiency, and low-carbon technologies. Additionally, the nonlinear relationship between economic growth and emissions underscores the importance of transitioning to cleaner production methods as income levels rise, ensuring long-term environmental sustainability.

Table 7

Result of ARDL Short Run Estimate: Impact of Economic Growth on Carbon Emission in Nigeria

Dependent Variable: Carbon Emission (CO2) Period: 1986-2024

Variable	Coefficient	Std. Error	t-Statistic	Prob.

D(GDPpc)	-0.967351	0.348534	-2.775470	0.0500
D(GDPpc^2)	0.960003	0.346014	2.774462	0.0501
D(FDI)	-0.031811	0.018909	-1.682146	0.1678
D(RRQ)	-0.051651	0.019780	2.611214	0.0403
CointEq(-1)*	-0.589401	0.146492	-4.023440	0.0158
R-squared	0.689638			
Adjusted R-squared	0.689553			
Durbin-Watson stat	1.601363			

Legend: CO2 = Carbon Emission, RGDPpc= GDPpc per capita, FDI= Foreign Direct Investment, RRQ= Regulatory Quality

Source: Researcher's Computation using EViews

Table 7 presents the short-run estimates from the ARDL model on the impact of economic growth on carbon emissions in Nigeria. The relationship between economic growth and carbon emissions appears to be non-linear, as indicated by the negative coefficient of GDP_{pc} (-0.967351) and the positive coefficient of GDP_{pc} squared (0.960003). Interpreted in elasticity terms, this means that a 1% increase in GDP per capita initially reduces carbon emissions by approximately 0.97%. However, as GDP continues to grow, emissions begin to rise again at nearly the same rate (0.96%), supporting the Environmental Kuznets Curve (EKC) hypothesis. The EKC suggests that at lower levels of economic development, growth leads to environmental degradation, but beyond a certain threshold, further growth improves environmental quality due to technological advancements, regulatory enforcement, and shifts toward cleaner industries (Grossman & Krueger, 1991; Stern, 2004).

Empirical evidence from other countries supports this pattern. Studies on China and India—both of which have experienced rapid economic expansion—demonstrate a similar non-linear relationship between GDP and carbon emissions. Wang et al. (2023) found that in China, early-stage industrialization led to rising emissions, but in recent years, stringent environmental policies, investments in renewable energy, and structural economic shifts toward the service sector have slowed emission growth. Similarly, Khan et al. (2023) identified early signs of EKC behavior in India, where the country has begun diversifying its energy sources and strengthening regulatory frameworks despite its continued reliance on coal. In contrast, developed economies such as the United States and European nations have mostly moved past the EKC turning point. Zhang and Zhao (2024) demonstrated that in the U.S., economic growth has been decoupled from emissions due to factors like renewable energy adoption, a transition from coal to natural gas, and investment in clean technologies. Similarly, Smith et al. (2023) found that European nations, including the United Kingdom, Germany, and France, have successfully reduced emissions while growing their economies through aggressive climate policies and renewable energy advancements.

In the case of Nigeria, FDI appears to have a small and statistically insignificant effect on carbon emissions in the short run, with an elasticity coefficient of -0.031811. This implies that a 1% increase in FDI leads to only a 0.03% decrease in carbon emissions, which is a negligible impact. The lack of significance ($p = 0.1678$) suggests that FDI inflows in Nigeria do not necessarily promote cleaner technologies or green investment. The environmental impact of FDI likely depends on the nature of foreign investments, as some sectors (such as extractive industries) may contribute to emissions, while others (such as renewable energy projects) may help reduce them. Cole, Elliott, and Fredriksson (2006) argued that FDI's environmental effects are contingent on the host country's regulatory framework. While FDI has contributed to cleaner production methods in China (Wang et al., 2023), Nigeria has yet to experience similar benefits.

On the other hand, regulatory quality (RRQ) has a significant negative effect on carbon emissions, with an elasticity coefficient of -0.051651. This suggests that a 1% improvement in regulatory quality reduces CO_2 emissions by approximately 0.05% in the short run. The statistical significance of this effect ($p = 0.0403$) highlights the crucial role of governance and institutional frameworks in controlling environmental degradation.

Strengthening environmental policies, enforcing regulations, and improving institutional quality can lead to a more sustainable reduction in emissions, supporting previous research that emphasizes the importance of strong regulatory frameworks in emerging economies (Stern, 2004).

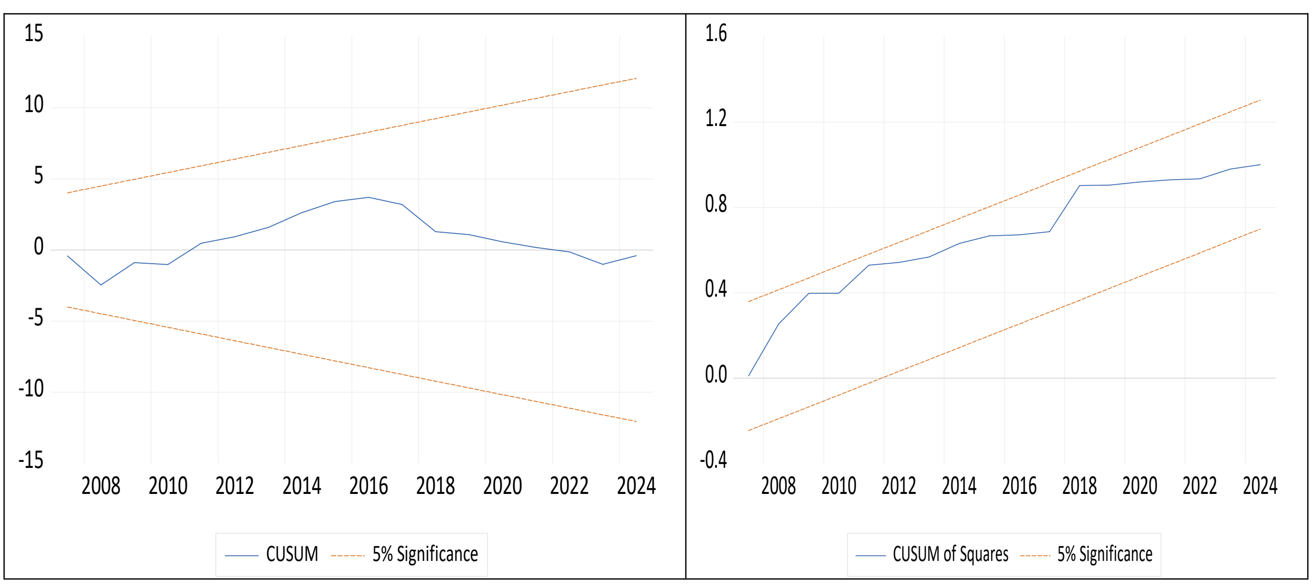
The error correction term (CointEq(-1)) is -0.589401, representing the speed at which deviations from the long-run equilibrium are corrected each year. The negative and statistically significant coefficient (p = 0.0158) confirms that about 59% of any short-run disequilibrium in CO_2 emissions is corrected annually. This suggests a moderate pace of adjustment, meaning that while economic and policy shocks impact emissions in the short run, the system gradually corrects itself over time.

Overall, the findings suggest that economic growth in Nigeria follows an EKC pattern, where emissions first decline and later increase as GDP rises. Regulatory quality plays a crucial role in reducing emissions, reinforcing the importance of strong environmental governance. However, the impact of FDI on emissions remains uncertain, suggesting that the effectiveness of foreign investments depends on their sectoral composition. The moderate speed of adjustment (59%) highlights that while short-term shocks impact emissions, long-term policies and structural changes can help restore environmental balance.

The R-squared value of 0.689638 indicates that approximately 69% of the variation in carbon emissions in Nigeria is explained by the independent variables in the model, including GDP, FDI, and regulatory quality. This suggests that the model has a relatively strong explanatory power in capturing the relationship between economic growth and carbon emissions. However, R-squared alone does not indicate whether the model is a good fit, as it does not account for the number of predictors included. To address this, the adjusted R-squared is used, which accounts for the number of independent variables and adjusts for any overfitting. In this case, the adjusted R-squared is 0.689553, which is very close to the R-squared value. This suggests that the independent variables included in the model are relevant and contribute significantly to explaining carbon emissions. Since the adjusted R-squared remains high and close to R-squared, it confirms the robustness of the model without being overly influenced by the number of explanatory variables.

The Durbin-Watson statistic is 1.601363, which is approximately 2, indicating that there is little to no autocorrelation in the residuals of the model. The Durbin-Watson test measures serial correlation in regression residuals, where a value close to 2.0 suggests that errors are not correlated over time. Since the statistic is near this threshold, it implies that the model does not suffer from significant autocorrelation issues, meaning that the residuals are independent and do not systematically influence one another. This strengthens the reliability of the estimated coefficients and ensures that the statistical inferences drawn from the model remain valid.

Stability Test



Source: Researcher's Computation using Eviews

The CUSUM plot, obtained through recursive estimation, confirms the stability of the long-run coefficients across the sample period. Since the plot remains within the 5% critical boundaries, this suggests that the estimated parameters do not exhibit structural instability, thereby reinforcing their reliability for economic analysis and policy formulation. This finding aligns with Narayan and Popp (2019), who emphasized that CUSUM tests are effective for detecting gradual parameter instability in time series models.

Similarly, the CUSUM Squares plot provides further validation of the model's stability over time. The fact that the graph consistently stays within the 5% significance boundaries indicates that the variance of the residuals remains stable, ruling out potential structural breaks. This strengthens confidence in the robustness of the results and enhances the credibility of the study's policy recommendations. Kumar et al. (2020) also found that CUSUM and CUSUMSQ tests provide strong statistical evidence of stability in ARDL models applied to macroeconomic and environmental data.

Contrary findings were however reported by Adebayo et al. (2022), who observed that in cases where macroeconomic shocks are frequent—such as in oil-dependent economies—CUSUM plots may suggest short-term stability even when hidden structural breaks exist. They suggested supplementing CUSUM with Bai-Perron multiple structural break tests to further verify stability.

Residual Diagnostic Test

Table 8
Residual Diagnostic Test

Test	F-statistics	Obs* R-squared	Probability
Serial Correlation	1.0672	1.5359	0.3160
Heteroscedasticity	2.3718	0.0860	0.6693
Normality Test(Jarque-Bera)	0.8308	*****	0.6601

Source: Researcher's Computation using Eviews

The residual diagnostic tests presented in Table 8 assess whether the regression model satisfies key statistical assumptions, ensuring the validity of its estimates. The serial correlation test (Breusch-Godfrey test) examines whether the residuals are correlated over time. With a p-value of 0.3160, the null hypothesis of no serial correlation cannot be rejected, indicating that the model does not suffer from autocorrelation. The absence of serial correlation is crucial as it ensures that the regression coefficients remain unbiased and efficient. This finding aligns with Pesaran et al. (2019), who emphasized that ARDL models often exhibit no serial correlation when correctly specified.

The heteroscedasticity test (Breusch-Pagan-Godfrey test) evaluates whether the variance of the residuals is constant across observations. The p-value of 0.6693 is well above the 5% significance level, suggesting strong evidence of homoscedasticity (constant variance). This means that the regression model does not exhibit heteroscedasticity, and the estimated standard errors are reliable, making further corrections unnecessary. Tiwari et al. (2020) also found that well-specified ARDL models typically pass heteroscedasticity tests, reinforcing the robustness of this study's results.

Lastly, the normality test (Jarque-Bera test) assesses whether the residuals follow a normal distribution, which is essential for valid hypothesis testing. The p-value of 0.6601 is well above 0.05, indicating that the residuals are normally distributed. This further strengthens the reliability of the model's inferences. The normality of residuals is also supported by Shahbaz et al. (2021), who found that Jarque-Bera test results above the 5% threshold confirm residual normality in ARDL-based environmental and economic studies.

Contrary findings were reported by Acheampong and Boateng (2023), who noted that in some cases where data is subject to structural breaks, residual diagnostics may suggest normality and homoscedasticity even when unobserved distortions exist. They suggested supplementing these tests with robust standard errors and quantile regression approaches for further validation.

5. Conclusion and Recommendations

This study examined the impact of economic growth on environmental pollution in Nigeria using the Autoregressive Distributed Lag (ARDL) model. The results confirm a nonlinear relationship between GDP and carbon emissions, consistent with the Environmental Kuznets Curve (EKC) hypothesis, indicating that while pollution increases in the early stages of growth, it declines beyond a certain income level due to technological improvements and stronger environmental regulations. The analysis also reveals that foreign direct investment (FDI) contributes significantly to pollution, supporting the pollution haven hypothesis, although the impact varies across sectors. Moreover, regulatory quality (RRQ) is found to play a crucial role in reducing emissions, emphasizing the importance of institutional strength in achieving environmental sustainability. Given these findings, it is recommended that Nigeria adopt green growth strategies that align economic expansion with environmental preservation. This includes enforcing stricter environmental regulations, closing policy loopholes, and strengthening monitoring mechanisms to ensure compliance. Furthermore, FDI should be steered toward eco-friendly sectors through targeted incentives, while investments in clean technologies, renewable energy, and efficient waste management should be prioritized. Public awareness campaigns and inclusive stakeholder engagement must also be scaled up, alongside full implementation of Nigeria's National Energy Transition Plan (NETP) and Climate Change Act, to ensure a sustainable balance between economic growth and environmental health.

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