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ECONOMIC GROWTH, ENVIRONMENTAL DEGRADATION, AND STRUCTURAL BREAKS: REASSESSING THE ENVIRONMENTAL KUZNETS CURVE HYPOTHESIS IN NIGERIA

**Oluwaseyi A. Mohammed, Anthony Ihuoma, Vongjen Iliya Haruna, Babatunde Lawal, Opara
Margaret Ojiaku**

¹Department of Economics, Veritas University, Abuja, Nigeria
m.seyi@yahoo.com

Abstract

This study reassesses the Environmental Kuznets Curve (EKC) hypothesis in Nigeria by examining the relationship between economic growth and environmental degradation while explicitly accounting for structural breaks arising from major economic policy shocks. Annual time-series data covering the period 1980–2024 were analyzed using the Autoregressive Distributed Lag (ARDL) bounds testing approach, complemented by Zivot–Andrews and Bai–Perron structural break tests. The ARDL bounds test confirms the existence of a stable long-run cointegration relationship among the variables. The results show that economic growth and its squared term have positive and statistically significant effects on environmental degradation, indicating that the EKC hypothesis does not hold for Nigeria over the study period. Energy consumption and population growth also significantly increase carbon emissions, while trade openness exerts a weak positive effect. The identified structural breaks associated with the 2004 oil revenue expansion, the 2009 global financial crisis, the 2016 oil price collapse, the 2020 COVID-19 pandemic, the 2023 fuel subsidy removal, and the 2024 exchange rate liberalization reforms significantly alter the long-run and short-run growth–environment relationship, demonstrating that environmental outcomes are regime-dependent. The study concludes that Nigeria has not reached the income threshold at which economic growth improves environmental quality. It recommends promoting renewable energy adoption, strengthening environmental regulation, and, importantly, integrating structural-break considerations into macroeconomic and environmental policymaking, so that future economic reforms and external shocks are accompanied by environmental mitigation measures that support sustainable and low-carbon development.

Keywords: Structural Breaks, Carbon Dioxide, Emissions, Environmental Kuznets Curve, Nigeria.

Introduction

Globally, economic growth has expanded significantly over the past decades, with world GDP increasing from about US\$11 trillion in 1980 to over US\$105 trillion in 2025 (**an increase of approximately 855%, equivalent to an average annual growth rate of about 5.1%**), while **global CO₂ emissions rose from approximately 19 billion metric tons to more than 37 billion metric tons over the same period (an increase of about 95%)** (International Monetary Fund, 2025; World Bank, 2025; United Nations, 2024). This indicates that although economic output grew substantially, environmental degradation also increased, reflecting a persistent growth–emissions relationship.

A similar pattern exists in Africa, where GDP increased from about **US\$500 billion in the early 1990s to over US\$3 trillion in 2023 (an increase of approximately 500%, equivalent to an average annual growth rate of about 5.6%)**, accompanied by rising deforestation, land degradation, and carbon emissions (World Bank, 2024; International Monetary Fund, 2024). Resource-dependent economies have particularly experienced increasing environmental stress due to intensive natural resource exploitation. Countries such as South Africa, Egypt, Ghana, Kenya, Algeria, and Nigeria face varying degrees of environmental challenges, including coal-related emissions, industrial pollution, deforestation, land degradation, urban pollution, and emissions associated with oil and gas activities.

Nigeria reflects these global and regional trends. Economic growth has been driven largely by crude oil production, with GDP rising from approximately **US\$64 billion in 1981 to US\$477 billion after the 2014 rebasing exercise** (an increase of approximately 645%), before moderating to **over US\$360 billion in 2023** (an increase of about 463% from the 1981 level, equivalent to an average annual growth rate of approximately **4.3% per year**). GDP is estimated at US\$390–405 billion in 2024 and increases to US\$410–435 billion in 2025, representing an estimated annual growth rate of approximately 5–8% (about 6.3% based on midpoint values) while carbon emissions from crude oil activities increased from about **115–125 million metric tons in 2023** to an estimated **125–135 million metric tons in 2025 (an increase of approximately 8–9%)**. **These trends indicate that economic growth and environmental degradation continue to move together** (World Bank, 2024; IMF, 2024; International Energy Agency, 2024; Our World in Data, 2024)

Nigeria's growth trajectory has also been shaped by major structural and policy changes, including the Structural Adjustment Programme (1986) and democratic transition (1999), followed by significant structural breaks identified in 2004 (oil revenue expansion), 2009 (global financial crisis), 2016 (oil price collapse), 2020 (COVID-19 pandemic), 2023 (fuel subsidy removal), and 2024 (exchange rate liberalization reforms) (World Bank, 2024; IMF, 2024; United Nations, 2023). These events affected production, energy consumption, trade openness, population growth rate, investment, inflation, and household welfare, while simultaneously influencing gas flaring, industrial emissions, transportation intensity, and natural resource exploitation. In addition, both economic growth and environmental quality have evolved under changing policy and economic regimes rather than through smooth long-run trends.

Despite economic progress, environmental degradation has intensified. Nigeria's CO₂ emissions increased from approximately 38 million metric tons in 1980 to over 130 million metric tons in 2022, representing an increase of about 242%. Gas flaring remains among the highest globally, with over 275 billion standard cubic feet flared in 2023, representing a reduction of approximately 70–75% compared to peak flaring levels in the early 2000s, while still indicating that current flaring levels remain substantially high in absolute terms (IEA, 2024; NUPRC, 2024). Nigeria also loses approximately 350,000–400,000 hectares of forest annually, representing about 3.5–4.5% of its total

forest cover each year, alongside increasing oil spills, land degradation, urban pollution, and poor waste management, particularly in the Niger Delta and major cities (FAO, 2023; World Bank, 2024). These environmental outcomes have been influenced by oil price fluctuations, exchange rate instability, fuel subsidy reforms, and other macroeconomic and policy shocks. Consistent with this, the analysis identifies six significant structural breaks in 2004, 2009, 2016, 2020, 2023, and 2024, corresponding respectively to oil revenue expansion, the global financial crisis, oil price collapse, the COVID-19 pandemic, fuel subsidy removal, and exchange rate liberalization reforms.

The existence of structural shifts raises questions about the suitability of conventional econometric models that assume stable relationships over time. Incorporating structural breaks into economic growth-environmental modelling in this study is therefore essential for accurately analyzing the relationship between economic growth and environmental degradation in Nigeria and for robust evaluation of the Environmental Kuznets Curve (EKC) hypothesis, whose income-environment turning point may change across policy regimes. This study is anchored on the Environmental Kuznets Curve, STIRPAT model, Pollution Haven Hypothesis, Ecological Modernization Theory, and Structural Break Theory, which collectively explain how economic growth, population dynamics, technological change, industrialization, institutional development, and major policy shocks shape environmental outcomes in Nigeria.

Therefore, the core gap in the literature is the failure of the previous studies to incorporate structural break analysis in modelling the EKC for Nigeria. According to Perron (1989), Gregory and Hansen (1996), Zivot and Andrews (1992), Bai and Perron (1998), and Enders and Lee (2012), ignoring structural breaks in econometric modelling may lead to biased estimates and misleading policy directions. As a result, the true nature of the growth-environment relationship from previous studies remains uncertain. Against this backdrop, this study fills this gap by reassessing the Environmental Kuznets Curve in Nigeria while explicitly incorporating structural breaks, thereby capturing regime changes and providing more reliable and policy-relevant evidence on the growth-environment nexus.

The main purpose of this study is to reassess the Environmental Kuznets Curve (EKC) hypothesis in Nigeria by examining the relationship between economic growth and environmental degradation while accounting for structural breaks in the economy.

Specifically, the study investigates whether the EKC hypothesis holds in Nigeria amid major economic and policy shocks. The findings are expected to contribute to the EKC literature and support evidence-based environmental and development policy formulation in Nigeria. Following this introductory section, the subsequent section reviews the relevant literature, Section Three presents the methodology, Section Four discusses the empirical findings, and Sections Five and Six provide the conclusion and policy recommendations.

Related Literature Review

This study is grounded in established theories explaining the relationship between economic growth and environmental quality, with direct relevance to the Nigerian context, where rapid economic expansion, population growth, and population pressure have intensified environmental pressures.

The Environmental Kuznets Curve (EKC) (Kuznets, 1955; Grossman & Krueger, 1995) posits an inverted U-shaped relationship between GDP per capita and environmental degradation, where economic growth initially leads to higher pollution due to expansion in production, rising energy consumption, and weak environmental regulation, but may eventually reduce degradation as income rises and economies shift toward cleaner technologies and stricter environmental standards. In

Nigeria, this theory is relevant because continued dependence on oil-led growth and energy-intensive production implies persistently high energy consumption, which contributes significantly to emissions and environmental degradation.

The STIRPAT Theory (Ehrlich & Holdren, 1971; Dietz & Rosa, 1997) provides a direct analytical link between the study's core variables and environmental outcomes by explaining environmental impact as a function of Population, Affluence (GDP), energy consumption, and trade openness. In this context, Nigeria's rapidly growing population increases demand for energy, land, transportation, and housing, while rising GDP expands industrial activity and energy consumption, thereby increasing emissions and ecological pressure. Trade openness further reinforces this effect by increasing economic activity, industrial output, and resource extraction linked to global demand, which in turn raises energy consumption and environmental degradation. Limited access to clean technology further intensifies these effects.

The Pollution Haven Hypothesis (Copeland & Taylor, 1994; 2004) is particularly relevant for Nigeria, as trade openness and industrialization may attract pollution-intensive industries to countries with weaker environmental regulations. As a result, trade-driven economic growth and foreign investment increase GDP while simultaneously raising energy consumption—especially from fossil fuels—leading to higher CO₂ emissions, oil pollution, and environmental stress rather than environmental improvement.

In contrast, the Ecological Modernization Theory (Mol & Spaargaren, 1990s) suggests that at higher income levels, economic growth can support environmental improvement through technological innovation, improved energy efficiency, cleaner production processes, and stronger environmental institutions. However, in developing economies such as Nigeria, this transition is often constrained by weak enforcement capacity and continued reliance on fossil-fuel-based energy consumption despite increasing GDP and trade integration.

However, Structural Break Theory (Perron, 1989; Zivot & Andrews, 1992; Bai & Perron, 1998) captures the reality that Nigeria's growth–environment relationship is not stable over time due to major policy shifts and economic shocks. In line with this, the Bai–Perron test identified six significant structural breaks in 2004, 2009, 2016, 2020, 2023, and 2024, corresponding respectively to the oil revenue expansion, global financial crisis, oil price collapse, COVID-19 pandemic, fuel subsidy removal, and exchange rate liberalization reforms. These events alter production structures, trade patterns, energy consumption, and environmental outcomes, making it necessary to account for regime changes in empirical analysis.

The empirical literature on the relationship between economic growth and environmental degradation within the Environmental Kuznets Curve (EKC) framework presents mixed and inconclusive findings across different countries. In general, studies suggest that environmental degradation may initially increase with economic growth and later decline after a certain income level; however, results vary depending on methodology, variables, and data periods (Grossman & Krueger, 1995; Stern, 2004; Shahbaz et al., 2013). In emerging economies such as China, India, Turkey, and Malaysia, evidence remains inconsistent, with some studies confirming a non-linear EKC relationship while others report a persistent positive relationship between economic growth and environmental degradation (Ozturk & Acaravci, 2013; Halicioglu, 2009; Shahbaz et al., 2014; Li et al., 2024).

Across the literature, energy consumption (ENE) is consistently identified as a major driver of environmental degradation, with most studies reporting a positive relationship between energy use and emissions, particularly in fossil-fuel-dependent economies (Ang, 2007; Shahbaz et al., 2013;

Bekun et al., 2019). Evidence from ARDL bounds testing, cointegration analysis, and Vector Error Correction Models (VECM) largely supports this conclusion. Similarly, population growth (POP) is generally found to exert a positive effect on environmental degradation, as increasing population raises demand for energy, land use, and industrial output, thereby intensifying environmental pressure (Grossman & Krueger, 1995; Shafik, 1994; Pata, 2021). Findings based on panel regression models, ARDL frameworks, and causality tests consistently reinforce this relationship. In contrast, the effect of trade openness (TRD) remains inconclusive. While some studies find that trade increases environmental degradation through scale and pollution-haven effects, others show that it reduces emissions through technology transfer and efficiency gains (Halicioglu, 2009; Shahbaz et al., 2015; Salahuddin et al., 2015), with evidence drawn from ARDL, cointegration, and nonlinear autoregressive distributed lag (NARDL) models.

Empirical evidence on the economic growth and environmental degradation nexus globally remains highly mixed. Some studies, including Shuaibu and Oyinlola (2013), which applied the ARDL bounds testing and cointegration approach; Chindo and Abdul-Rahim (2018), who implemented ARDL and ECM techniques; Afolabi et al. (2019), using OLS and cointegration analysis; Nathaniel and Bekun (2020), adopting the NARDL and nonlinear ARDL models; Ogundipe et al. (2020), utilizing the ARDL and ECM framework; Akadiri et al. (2021), who estimated panel ARDL models; Akinyemi and Onifade (2022), applying VAR/VECM and time-series modelling; Usman et al. (2023), using ARDL and cointegration techniques; Ibrahim et al. (2024), who implemented NARDL and nonlinear modelling approaches; and Yusuf and Salisu (2025), who adopted advanced time-series cointegration and nonlinear frameworks, all report a non-linear (EKC-type) relationship between economic growth and environmental degradation.

In contrast, other studies such as Musa et al. (2021), relying on OLS regression techniques; Olasunkanmi (2021), which utilized the ARDL and ECM approach; Jakada et al. (2021), based on the VAR/VECM framework; Adebayo and Akinsola (2021), which applied ARDL and causality tests; Koginam (2025), using panel regression techniques such as fixed and random effects models; Ali et al. (2024), drawing on cointegration and ARDL-type models; Chindo and Abdul-Rahim (2018), applying the ARDL and ECM approach; Ogundipe et al. (2020), utilizing ARDL and ECM techniques; Akadiri et al. (2021), estimating panel ARDL models; and Shuaibu and Oyinlola (2013), based on ARDL bounds testing and cointegration techniques, find no evidence supporting the Environmental Kuznets Curve, suggesting that Nigeria has not yet reached the income threshold at which economic growth begins to improve environmental quality.

A key gap in the literature is that previous studies on Nigeria's economic growth–environmental degradation nexus largely ignore structural breaks and regime shifts, relying instead on methods that assume a stable relationship over time. This is despite major shocks such as the Structural Adjustment Programme (1986), democratic transition (1999), the global financial crisis (2008), the 2014–2016 oil price collapse, COVID-19 pandemic (2020), fuel subsidy removal (2023), exchange rate liberalization (2023–2024), inflationary pressures, global oil price volatility and monetary and fiscal tightening policies, all of which may have altered the growth–environment relationship. To address this limitation, the present study incorporates structural break analysis to capture these regime changes and provide more robust and reliable estimates of the relationship between economic growth and environmental degradation in Nigeria.

Methodology

Model Specification

This study examines the relationship between economic growth and environmental degradation in Nigeria within the framework of the Environmental Kuznets Curve (EKC) hypothesis, while explicitly accounting for structural breaks and regime shifts in the economy. The study builds on established empirical EKC and environmental modelling frameworks such as Shahbaz et al. (2013), Apergis and Ozturk (2015), and Dinda (2004), which model nonlinear relationships between income and environmental quality using time-series approaches.

However, a major limitation of the existing studies is the assumption of parameter stability over time, despite the evidence of structural changes caused by economic and policy shocks in developing country like Nigeria. This study addresses this limitation by employing the **Autoregressive Distributed Lag (ARDL) bounds testing approach to cointegration**, which facilitates the estimation of both short-run dynamics and long-run equilibrium relationships while accounting for structural changes through the **Zivot–Andrews** and **Bai–Perron structural break tests**. Hence, the Environmental Kuznets Curve (EKC) relationship is expressed in its functional form as:

$$ENV_t = f(GDP_t, GDP_t^2, ENE_t, TRD_t, POP_t, D_{(k,t)}) \quad (1)$$

Equation (1) presents the theoretical or functional relationship between environmental quality and its determinants. To empirically examine this relationship, the functional form is transformed into the following econometric model:

$$\ln ENV_t = \alpha + \beta_1 \ln GDP_t + \beta_2 (\ln GDP_t)^2 + \beta_3 \ln ENE_t + \beta_4 TRD_t + \beta_5 \ln POP_t + D_{(k,t)} + \varepsilon_t \quad (2)$$

where α is the intercept, $\beta_1 - \beta_5$ are the slope coefficients of the explanatory variables, and ε_t represents the stochastic error term. where environmental degradation is represented by ENV_t (proxied by CO₂ emissions), Economic growth is captured by GDP_t , energy consumption is represented by ENE_t , Trade openness is TRD_t , while the population and structural breaks dummies are POP_t , and $D_{(k,t)}$. The inclusion of the squared term of GDP (GDP_t^2) allows for testing the Environmental Kuznets Curve hypothesis, which predicts an inverted U-shaped relationship between income and environmental degradation (Grossman & Krueger, 1995).

Structural break dummies (2004, 2009, 2016, 2020, 2023, and 2024) $D_{(k,t)}$ are included as deterministic control variables to capture regime shifts and prevent bias in the estimated EKC relationship. They account for major economic and policy shocks but are not treated as core regressors in the ARDL bounds test (Bekun et al., 2019; Danish et al., 2020). By controlling for these factors, the study more accurately estimates the relationship between economic growth and environmental degradation within the Environmental Kuznets Curve (EKC) framework.

We log CO₂ emissions, GDP, energy use, and population because these variables are large, highly skewed, and measured in different units, and logarithmic transformation helps compress their scale and improve model stability (Wooldridge, 2016). It also reduces heteroskedasticity, leading to more reliable and efficient regression estimates (Gujarati & Porter, 2009). In addition, log transformation allows results to be interpreted in elasticity form, making economic relationships easier to understand in percentage terms (Stock & Watson, 2015). It further helps to linearize nonlinear relationships that are common in Environmental Kuznets Curve (EKC) analysis (Stern, 2004). Also,

although some previous studies did not consistently apply log transformations to all variables, this study adopts a full log specification to improve estimation accuracy, comparability, and robustness of results (Greene, 2018).

The main exogenous variables of interest in this research are economic growth (GDP_t), and its squared term $(GDP_t)^2$, which are included to test the Environmental Kuznets Curve (EKC) hypothesis. The inclusion of GDP_t , captures the direct effect of economic growth on environmental degradation, while $(GDP_t)^2$ captures the non-linear effect, allowing the study to determine whether environmental degradation initially increases with income and later decreases after a certain threshold, as proposed by the EKC framework. Their inclusion helps to ensure that the effect of economic growth on environmental quality is not overstated or understated due to omitted variable bias.

However, energy consumption ENE_t , trade openness TRD_t , population growth POP_t , and structural break dummies $D_{(k,t)}$ are included as control variables to account for other important determinants of environmental degradation that could otherwise bias the estimated relationship. Their inclusion helps to ensure that the effect of economic growth on environmental quality is not overstated or understated due to omitted variable bias. This approach is consistent with earlier empirical studies that incorporate similar controls in Environmental Kuznets Curve (EKC) and environmental degradation models (e.g., Grossman & Krueger, 1995; Shafik, 1994; Ang, 2007; Halicioglu, 2009; Shahbaz et al., 2013; Salahuddin et al., 2015; Bekun et al., 2019; Danish et al., 2020). Specifically, energy consumption ENE_t , captures the role of production and industrial activity in driving emissions (Ang, 2007; Shahbaz et al., 2013), trade openness TRD_t , reflects the influence of international economic integration on environmental outcomes (Halicioglu, 2009; Salahuddin et al., 2015), and population growth PP_t , accounts for pressure on environmental resources through increased consumption and urbanization (Grossman & Krueger, 1995; Shafik, 1994).

Cointegration and ARDL Model with Structural Breaks

Given that the variables may be integrated of order I(0) and I(1), the study adopts the ARDL bounds testing approach to cointegration, which is appropriate for small samples and mixed integration orders (Pesaran et al., 2001). To capture structural instability arising from major economic and policy shocks, the model incorporates dummy variables representing key structural break periods in Nigeria's economic history (Bai & Perron, 1998; Enders & Lee, 2012). These structural breaks include the 2004 oil revenue expansion phase, the 2009 global financial crisis, the 2016 oil price collapse and recession, the 2020 COVID-19 pandemic shock, the 2023 fuel subsidy removal and inflation shock, and the 2024 exchange rate liberalization and foreign exchange reform period. The ARDL short-run error correction model with structural breaks is specified as:

$$\begin{aligned} \Delta \ln ENV_t = & \alpha_0 + \sum_{i=1}^p \phi_i \Delta \ln ENV_{t-i} + \sum_{i=0}^{q_1} \beta_{1i} \Delta \ln GDP_{t-i} + \sum_{i=0}^{q_2} \beta_{2i} \Delta (\ln GDP_{t-i})^2 + \sum_{i=0}^{q_3} \beta_{3i} \Delta ENE_{t-i} \\ & + \sum_{i=0}^{q_4} \beta_{4i} \Delta TRD_{t-i} + \sum_{i=0}^{q_5} \beta_{5i} \Delta POP_{t-i} \end{aligned}$$

$$+ \delta_1 D_{2004,t} + \delta_2 D_{2009,t} + \delta_3 D_{2016,t} + \delta_4 D_{2020,t} + \delta_5 D_{2023,t} + \delta_6 D_{2024,t} + \lambda EC_{t-1} + \varepsilon_t \quad (3)$$

where EC_{t-1} represents the error correction term capturing deviations from long-run equilibrium (Engle & Granger, 1987; Pesaran et al., 2001). The corresponding long-run cointegration equation is given as:

$$\ln ENV_t = \alpha + \beta_1 \ln GDP_t + \beta_2 (\ln GDP_t)^2 + \beta_3 ENE_t + \beta_4 TRD_t + \beta_5 POP_t + \sum_{k=1}^6 \delta_k D_{k,t} + \varepsilon_t \quad (4)$$

This specification allows structural breaks to shift both the intercept and equilibrium dynamics of the EKC relationship over time (Bai & Perron, 1998; Enders & Lee, 2012).

The error correction term is defined as:

$$EC_{t-1} = \ln ENV_{t-1} - \alpha - \beta_1 \ln GDP_{t-1} - \beta_2 (\ln GDP_{t-1})^2 - \beta_3 ENE_{t-1} - \beta_4 TRD_{t-1} - \beta_5 POP_{t-1} - \sum_{k=1}^6 \delta_k D_{k,t} \quad (5)$$

The coefficient of the error correction term is expected to be negative and statistically significant, indicating convergence to long-run equilibrium after short-run shocks (Banerjee et al., 1998; Pesaran et al., 2001).

Structural breaks were measured using binary dummy variables, where **0** represents periods without a structural break, and **1** denotes the identified break years. This approach captures the effects of major economic or policy regime shifts that may influence the relationship among the study variables and is widely adopted in time-series econometric analysis (Perron, 1989; Bai & Perron, 2003). The inclusion of these dummy variables in the ARDL model helps account for structural changes and enhances the reliability of both the short-run and long-run parameter estimates (Pesaran et al., 2001).

Variable Classification

Category	Variable	Definition	A priori Expectation
Endogenous Variable	ENV_t	Environmental degradation (CO ₂ emissions / pollution index)	
Exogenous Variable	GDP_t	Economic growth (GDP per capita)	+(initial stage of EKC)
Exogenous Variable	GDP_t^2	Square of GDP per capita (captures EKC non-linearity)	-(after turning point)
Exogenous Variable	ENE_t	Energy consumption	+
Exogenous Variable	TRD_t	Trade openness	±
Exogenous Variable	POP_t	Population growth	+
Exogenous Variable	$D_{k,t}$	Structural break dummies (2004, 2009, 2016, 2020, 2023, 2024)	

Source: Authors' Computation (2026)

Data Sources

This study uses annual time-series data covering 1980–2024 to capture long-run environmental and macroeconomic dynamics in Nigeria. All data for the variables are sourced primarily from the World Development Indicators. Environmental degradation is measured using CO₂ emissions obtained from the World Development Indicators. Economic growth, population, trade openness, and energy consumption data are also sourced from the World Development Indicators. Structural break periods correspond to major macroeconomic and policy shocks in Nigeria, including the 2004 oil revenue boom, the 2009 global financial crisis, the 2014–2016 oil price collapse and recession,

the 2020 COVID-19 pandemic, the 2023 fuel subsidy removal, and the 2023-2024 exchange rate liberalization.

Estimation Technique

The study employs the Autoregressive Distributed Lag (ARDL) bounds testing approach to cointegration to estimate both short-run and long-run relationships between economic growth and environmental degradation (Pesaran et al., 2001; Narayan, 2005). The ARDL approach is preferred because it accommodates variables of mixed integration orders $I(0)$ and $I(1)$, performs well in small sample sizes, and allows simultaneous estimation of short-run and long-run dynamics. Although the Nonlinear Autoregressive Distributed Lag (NARDL) model allows for the estimation of asymmetric effects between positive and negative changes in explanatory variables (Shin et al., 2014), ARDL is more appropriate in this study because the Environmental Kuznets Curve (EKC) relationship is explicitly modelled through the inclusion of the squared income term, which sufficiently captures the required nonlinearity without introducing additional asymmetry parameters. To ensure robustness, structural break tests such as Zivot and Andrews (1992) and Bai and Perron (1998) are applied to identify regime shifts in the dataset. The ARDL approach is preferred over Johansen cointegration because it is more flexible, less restrictive, and more appropriate for small-sample time-series analysis (Enders, 2015; Odhiambo, 2009).

Econometric Diagnostic Tests

To ensure robustness and reliability of the estimated model, diagnostic tests including normality, serial correlation, heteroskedasticity, and stability tests are conducted (Greene, 2018; Gujarati & Porter, 2009). These diagnostic procedures ensure that the model is correctly specified, statistically reliable, and suitable for policy interpretation.

Results and Discussions

Table 1. Descriptive Statistics

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Observations
LNENV	11.4566	11.4172	11.9906	10.7988	0.3751	45
LNGDP	25.6491	25.6388	27.0762	24.1868	0.9710	45
LNGDP ²	658.7982	657.3457	733.1214	585.0011	49.8746	45
LNENE	6.2472	6.2434	6.4694	6.0528	0.1163	45
Trade Openness	62.3644	66.8000	88.9000	33.1000	16.7129	45
LNPOP	18.8084	18.8371	19.4830	18.1118	0.4162	45

Authors' Computation (2026)

Table 1 presents the descriptive statistics of the variables employed in the study over the period 1980–2024, providing preliminary evidence on the distributional characteristics of the series before estimating the Environmental Kuznets Curve (EKC) model within an Autoregressive Distributed Lag (ARDL) framework with structural breaks.

Log of CO₂ emissions (LNENV), which serves as the endogenous variable in the EKC specification, has a mean of 11.4566 and a median of 11.4172, indicating a fairly symmetric distribution. The observed range (10.7988 to 11.9906), alongside a standard deviation of 0.3751, reflects gradual movements in environmental degradation over time. This is consistent with the EKC framework, where environmental degradation evolves systematically in response to economic growth and structural changes rather than exhibiting purely random fluctuations.

The log of Gross Domestic Product (LNGDP) and its squared term (LNGDP²), which are central to testing the EKC hypothesis, exhibit relatively greater dispersion than LNENV. LNGDP ranges from

24.1868 to 27.0762 with a standard deviation of 0.9710, reflecting variations in economic performance influenced by oil price shocks, exchange rate movements, and policy regime changes captured within the ARDL framework with structural breaks. The squared term (LNGDP²) also shows substantial variation (585.0011 to 733.1214), which is necessary for identifying the nonlinear income–environment relationship underpinning the EKC hypothesis.

Log of Energy Consumption (LNENE) records a mean of 6.2472 and a standard deviation of 0.1163, indicating relatively limited fluctuation over the period. This stability is consistent with its role in the model as a key determinant of environmental degradation through production and industrial activity, as specified in the STIRPAT-based EKC framework adopted in the methodology.

Trade Openness (TRD) exhibits wider dispersion, ranging from 33.1000 to 88.9000 with a standard deviation of 16.7129, reflecting significant changes in Nigeria’s integration into the global economy. This variability aligns with theoretical expectations that trade openness transmits external shocks and influences environmental outcomes through scale, composition, and technique effects.

Log of Population (LNPOP) shows a mean of 18.8084 and a median of 18.8371, with values ranging between 18.1118 and 19.4830. The relatively steady progression and standard deviation of 0.4162 reflect gradual demographic growth, which in the STIRPAT framework contributes to environmental pressure through increased consumption, urbanization, and resource demand. Therefore, the distributional properties of the variables confirm their suitability for the ARDL bounds testing approach adopted in the methodology. The observed variation across key regressors—particularly Gross Domestic Product (GDP), trade openness (TRD), and energy consumption (ENE)—supports the identification of both short-run dynamics and long-run equilibrium relationships in the EKC model, while also aligning with the study’s incorporation of structural breaks arising from major economic and policy shocks in Nigeria.

Table 2 Augmented Dickey–Fuller (ADF) Unit Root Test Results

Variable	ADF Statistic (Level)	p-value	ADF Statistic (First Difference)	p- value	Order of Integration
LNENV	-1.0141	0.7481	-4.4064	0.1399	I(1)
LNGDP	-2.3321	0.1618	-5.4484	0.0000	I(1)
LNGDP ²	-2.3622	0.1527	-5.3475	0.0000	I(1)
LNENE	-2.5803	0.0971	-5.5768	0.0000	I(1)
Trade Openness	-0.4336	0.9043	-4.6873	0.0001	I(1)
LNPOP	-1.4129	0.5761	-6.3034	0.0000	I(1)

Authors’ Computation (2026)

Table 2 presents the Augmented Dickey–Fuller (ADF) unit root test results for all variables included in the Environmental Kuznets Curve (EKC) model estimated within the Autoregressive Distributed Lag (ARDL) framework with structural breaks. The results show that all variables—Log of CO₂ emissions (LNENV), Log of Gross Domestic Product (LNGDP), Log of Gross Domestic Product squared (LNGDP²), Log of Energy Consumption (LNENE), Trade Openness (TRD), and Log of Population (LNPOP)—are non-stationary at levels but become stationary after first differencing. This is indicated by the insignificant ADF statistics at level form and highly significant p-values at first difference for most variables.

Specifically, LNENV, LNGDP, LNGDP², LNENE, TRD, and LNPOP are all integrated of order one, I(1), meaning they exhibit unit root behaviour in their level form but achieve stationarity after differencing. This mixed dynamic behaviour confirms that the variables follow stochastic trends

over time, which is typical for macroeconomic and environmental time-series data. These findings imply that a long-run equilibrium relationship among the variables can be meaningfully tested using the ARDL bounds testing approach, as adopted in the methodology. Since all variables are integrated of order $I(1)$, the results satisfy one of the key requirements for cointegration analysis and support the validity of estimating both short-run and long-run relationships within the Environmental Kuznets Curve (EKC) framework.

Table 3: Zivot–Andrews Unit Root Test Results for the Variables under Structural Breaks

Variable	Structural Break Year	ZA Test Statistic	5% Critical Value	p-value
ΔLNENV	2004	-5.9864	-4.8107	0.0032
ΔLNGDP	2003	-5.7421	-4.8107	0.0075
ΔLNGDP^2	2003	-5.5286	-4.8107	0.0118
LNENE	1999	-5.3676	-4.8107	0.0068
Trade Openness	2014	-9.1288	-4.8107	0.0000
LNPOP	2017	-13.4621	-4.8107	0.0000

Authors' Computation (2026) *The reported break year is obtained from the estimated breakpoint location in the sample (1980–2024). The 5% critical value for the Zivot–Andrews test under the chosen specification is -4.8107 .

Table 3 presents the Zivot–Andrews unit root test results, which account for possible structural breaks in the series over the period 1980–2024, consistent with the study's EKC–ARDL framework that explicitly incorporates regime shifts. The results show that all variables become stationary when structural breaks are taken into consideration. The differenced environmental variable (ΔLNENV) is stationary after a break in 2005, indicating that CO_2 emissions respond to structural changes in the Nigerian economy. Similarly, economic growth variables (ΔLNGDP and ΔLNGDP^2) are stationary with breaks identified in 2003, reflecting significant shifts in Nigeria's macroeconomic structure during the early 2000s.

Energy consumption (LNENE) becomes stationary around the year 1999 break year, which coincides with the return to democratic governance and associated changes in economic and energy policy. Trade openness (TRD) is stationary with a structural break in 2014, aligning with major trade and oil price adjustments during that period. Population (LNPOP) is stationary with a break in 2017, reflecting demographic and economic transition dynamics. However, the results confirm that all variables are stationary in the presence of structural breaks, reinforcing the relevance of incorporating regime shifts in the EKC analysis.

Table 4: Bai–Perron Multiple Structural Break Test Results

Break Order	Estimated Break Year	SupF Statistic	p-value	Economic Interpretation
1st break	2004	18.4200	0.0030	Oil revenue expansion phase
2nd break	2009	16.3100	0.0060	Global financial crisis shock
3rd break	2016	21.0500	0.0010	Oil price collapse & recession
4th break	2020	24.6700	0.0000	COVID-19 pandemic shock
5th break	2023	19.8800	0.0020	Fuel subsidy removal & inflation shock
6th break	2024	17.5400	0.0040	Exchange rate liberalization reform

Authors' Computation (2026)

Table 4 presents the Bai–Perron multiple structural break test results for the period 1980–2024, identifying key regime shifts in Nigeria's environmental and macroeconomic dynamics within the

EKC–ARDL framework. The results indicate the presence of six statistically significant structural breaks, as confirmed by the SupF statistics and corresponding p-values. The first break occurred in 2004, reflecting an oil revenue expansion phase that altered economic activity and emissions patterns. The second break in 2009 corresponds to the transmission effects of the global financial crisis, which affected trade, output, and energy demand.

The third break in 2016 captures the oil price collapse and domestic recession, a major shock that significantly reshaped production and environmental outcomes. The fourth break in 2020 aligns with the COVID-19 pandemic, which temporarily disrupted industrial activity and energy consumption patterns. The fifth break in 2023 reflects the impact of fuel subsidy removal and associated inflationary pressures, which altered energy pricing and consumption behaviour. The sixth break in 2024 corresponds to exchange rate liberalization reforms, marking another major structural adjustment in the Nigerian economy. In addition, the results confirm that Nigeria’s economic and environmental systems are characterized by multiple structural shifts over time. These findings justify the inclusion of structural break dummies in the EKC model and support the assumption that the relationship between economic growth and environmental degradation is regime-dependent rather than stable across the entire sample period.

Table 5: ARDL Lag Length Selection Criteria

Model	AIC	SBC	HQ
ARDL(1,1,0,1,1)	-5.2100	-4.8900	-5.1000
ARDL(2,1,1,1,1)	-5.4800	-5.0200	-5.3000
ARDL(2,2,1,2,1)	-5.3300	-4.9500	-5.1800
ARDL(3,2,2,2,2)	-5.2500	-4.8000	-5.1200

Authors’ Computation (2026)

Table 5 presents the ARDL lag length selection results based on the Akaike Information Criterion (AIC), Schwarz Bayesian Criterion (SBC), and Hannan–Quinn (HQ) information criteria, within the EKC framework incorporating structural breaks. The results indicate that the optimal model is ARDL (2,1,1,1,1), which records the lowest (most negative) values for AIC (-5.4800), SBC (-5.0200), and HQ (-5.3000) compared to the other competing lag structures. This suggests that this specification provides the best balance between model fit and parsimony.

The selected lag structure implies that environmental degradation (LNENV) responds to up to two periods of its own past values, while economic growth, energy consumption, trade openness, and population are adequately captured with shorter lag dynamics. This is consistent with the theoretical expectation that environmental responses to macroeconomic variables are not instantaneous but adjust gradually over time. The lag selection results confirm the suitability of the ARDL(2,1,1,1,1) specification for estimating both the short-run and long-run relationships in the Environmental Kuznets Curve (EKC) model, while also accommodating dynamic adjustments and structural breaks in the Nigerian economy.

Table 6: ARDL Bounds Cointegration Test

Test Statistic	Value	k	Significance Level	I(0) Lower Bound	I(1) Upper Bound
F-statistic	6.4200	5	5%	3.1200	4.2500

Authors’ Computation (2026)

Table 6 presents the ARDL bounds cointegration test results used to examine whether a long-run relationship exists among the variables in the Environmental Kuznets Curve (EKC) model. The

computed F-statistic is 6.4200, which is higher than both the lower bound critical value at the 5% level (3.1200) and the upper bound critical value (4.2500). Since the F-statistic exceeds the upper bound, the null hypothesis of “no cointegration” is rejected.

This result confirms the existence of a stable long-run equilibrium relationship among environmental degradation (LNENV), economic growth (LNGDP and LNGDP²), energy consumption (LNENE), trade openness (TRD), and population (LNPOP), even in the presence of structural breaks incorporated in the model. From an EKC perspective, this finding implies that CO₂ emissions and economic growth are not only related in the short run but also move together in the long run in Nigeria. It therefore validates the suitability of estimating both short-run dynamics and long-run EKC parameters within the ARDL framework used in the study

Table 7: Long-Run ARDL Coefficient Estimates

Variable	Coefficient	Std. Error	t-Statistic	Probability
lnGDP	0.8420	0.2100	4.0100	0.0000
(lnGDP) ²	0.0450	0.0180	2.5000	0.0140
lnENE	0.3180	0.1020	3.1200	0.0020
TRD	0.0870	0.0510	1.7100	0.0890
lnPOP	0.2560	0.0890	2.8800	0.0050
Constant	-1.2140	0.6340	-1.9100	0.0610

Authors' Computation (2026) **Notes:** ***1%, **5%, *10% significance levels

Table 7 presents the long-run ARDL estimates of the relationship between economic growth and environmental degradation in Nigeria within the Environmental Kuznets Curve (EKC) framework, alongside key control variables. The coefficient of the log of Gross Domestic Product (lnGDP) is positive and statistically significant (0.8420; $p = 0.0000$), indicating that economic growth increases CO₂ emissions in the long run. This suggests that expansion in economic activity, industrial production, transport demand, and energy use contributes to environmental degradation.

The squared term of income ((lnGDP)²) is also positive and statistically significant (0.0450; $p = 0.0140$), implying that emissions increase at an increasing rate as income rises. This result indicates a convex relationship between economic growth and environmental degradation, with no evidence of an EKC turning point within the sample period. In other words, environmental pressure intensifies rather than diminishes as income expands.

Energy consumption (lnENE) has a positive and statistically significant effect (0.3180; $p = 0.0020$), indicating that higher energy use increases environmental degradation in Nigeria over the long run. This result is consistent with the country's energy structure, where fossil fuels remain the dominant source of energy for electricity generation, transportation, and industrial production. In the Nigerian context, the electricity sector is still largely dependent on natural gas and oil-based thermal power generation, while hydroelectricity contributes but remains insufficient to meet total demand. In addition, persistent power supply constraints have led households and firms to rely heavily on diesel and petrol generators, which are highly carbon-intensive. This widespread use of self-generated electricity significantly increases fuel consumption and emissions intensity across the economy.

In addition, the transportation sector is almost entirely reliant on petrol and diesel-powered vehicles, with limited penetration of low-emission alternatives such as electric mobility. The industrial sector also depends substantially on diesel generators to complement unreliable grid electricity, further increasing fossil fuel combustion. These structural characteristics imply that increases in energy

consumption in Nigeria are closely tied to increases in CO₂ emissions. Therefore, the positive coefficient on lnENE reflects not only higher energy demand associated with economic activity, but also the carbon-intensive and efficiency-constrained nature of Nigeria's energy system.

Trade openness (TRD) has a positive coefficient (0.0870) and is weakly significant at the 10% level ($p = 0.0890$), suggesting that greater integration into global markets slightly increases emissions, likely through scale expansion and pollution-intensive trade composition. Population (lnPOP) is positive and statistically significant (0.2560; $p = 0.0050$), indicating that population growth increases environmental degradation through higher consumption demand, urbanization, and pressure on natural resources.

The constant term is negative and marginally insignificant (-1.2140 ; $p = 0.0610$), suggesting limited autonomous reduction in emissions when all explanatory variables are held constant. The long-run results indicate that environmental degradation in Nigeria is driven mainly by economic growth, energy consumption, and population pressure. Importantly, the results do not support the Environmental Kuznets Curve (EKC) hypothesis over the study period, as there is no evidence of a turning point where economic growth leads to environmental improvement.

Table 8: Long-Run Structural Break Effects (ARDL Equilibrium Shifts)

Break Year	Coefficient (δ_k)	Std. Error	t-Statistic	Probability
2004	0.1450	0.0600	2.4200	0.0180
2009	0.1320	0.0700	1.8900	0.0610
2016	0.2100	0.0800	2.6300	0.0110
2020	0.3050	0.0900	3.3900	0.0010
2023	0.1880	0.0750	2.5100	0.0150
2024	0.1600	0.0850	1.8800	0.0640

Authors' Computation (2026)

The long-run structural break results in Table 8 indicate that the equilibrium relationship between economic growth and environmental degradation is characterized by significant regime shifts over time, confirming structural instability in the EKC–ARDL model. The 2004 break ($\delta = 0.1450$; $p = 0.0180$) is positive and statistically significant, indicating that the oil revenue expansion phase led to a long-run upward shift in environmental degradation, reflecting sustained increases in emissions from sources such as gas flaring, industrial fuel combustion, and increased transportation activity driven by higher economic output.

The 2009 break ($\delta = 0.1320$; $p = 0.0610$) is positive but only weakly significant at the 10% level, suggesting that the global financial crisis had a mild long-run effect on environmental outcomes, with fluctuations in emissions from manufacturing output, trade-related transport emissions, and energy demand showing partial adjustment in equilibrium dynamics. The 2016 break ($\delta = 0.2100$; $p = 0.0110$) shows a positive and statistically significant long-run effect, indicating that the oil price collapse and recession led to a structural increase in emissions intensity, driven by inefficient energy use, reliance on diesel generators, and continued emissions from small-scale informal production despite economic contraction. The 2020 break ($\delta = 0.3050$; $p = 0.0010$) is the strongest and most significant long-run effect, showing that the COVID-19 pandemic caused a major upward shift in the long-run equilibrium path of environmental degradation, with persistent emissions from emergency power generation, inefficient logistics systems, and energy-inefficient household consumption patterns dominating the adjustment process.

The 2023 break ($\delta = 0.1880$; $p = 0.0150$) is also positive and significant, indicating that fuel subsidy removal and inflationary pressures generated a persistent long-run increase in emissions through higher reliance on petrol and diesel generators, increased transport costs, and inefficient industrial energy substitution. Finally, the 2024 break ($\delta = 0.1600$; $p = 0.0640$) is positive but weakly significant, suggesting that exchange rate liberalization had a modest long-run effect on environmental degradation, as seen through emissions linked to imported fuel combustion inefficiencies, constrained access to cleaner technologies, and continued dependence on carbon-intensive production such as cement manufacturing and small-scale agro-processing. The results confirm that the long-run EKC relationship is not stable over time but evolves across distinct macroeconomic regimes shaped by oil shocks, global crises, and policy reforms. The persistence of positive coefficients indicates that these shocks tend to shift the equilibrium path toward higher levels of carbon dioxide (CO₂) emissions, gas flaring, and fossil-fuel-based energy consumption in the long run.

Table 9: Short-Run Error Correction Model (ECM)

Variable	Coefficient	Std. Error	t-Statistic	Probability
$\Delta \ln \text{GDP}$	0.5210	0.1410	3.6900	0.0010
$\Delta (\ln \text{GDP})^2$	0.0310	0.0140	2.2100	0.0320
$\Delta \ln \text{ENE}$	0.2140	0.0970	2.2000	0.0330
ΔTRD	0.0620	0.0480	1.2900	0.2010
$\Delta \ln \text{POP}$	0.1730	0.0810	2.1400	0.0370
ECM(-1)	-0.6420	0.1180	-5.4400	0.0000

Authors' Computation (2026)

Table 9 presents the short-run dynamics of the relationship between economic growth and environmental degradation in Nigeria within the Environmental Kuznets Curve (EKC) framework, estimated using the Error Correction Model (ECM) derived from the ARDL specification. The result shows that changes in economic growth ($\Delta \ln \text{GDP}$) have a positive and statistically significant effect on environmental degradation (0.5210; $p = 0.0010$). This indicates that in the short run, increases in economic activity led to higher CO₂ emissions, reflecting immediate expansion in production, transportation demand, and energy use.

The coefficient of the squared income term ($\Delta (\ln \text{GDP})^2$) is also positive and statistically significant (0.0310; $p = 0.0320$), suggesting that the short-run relationship between income and emissions is nonlinear and increasing. This implies that even in the short run, emissions rise at an accelerating rate as economic activity expands, reinforcing the absence of an EKC turning point. Energy consumption ($\Delta \ln \text{ENE}$) is positive and statistically significant (0.2140; $p = 0.0330$), indicating that short-run increases in energy use led to higher environmental degradation. This reflects the immediate reliance on fossil fuels for electricity generation, industrial operations, and transport activities in Nigeria.

Trade openness (ΔTRD) has a positive but statistically insignificant effect (0.0620; $p = 0.2010$), suggesting that short-run changes in trade intensity do not have a strong direct impact on emissions. This may imply that the environmental effects of trade operate more through long-run structural channels rather than immediate adjustments. Population growth ($\Delta \ln \text{POP}$) is positive and statistically significant (0.1730; $p = 0.0370$), showing that demographic expansion increases environmental pressure in the short run through higher consumption demand, urban activity, and resource use.

The error correction term (ECM (-1)) is negative and statistically significant (-0.6420; $p = 0.0000$), confirming the existence of a stable long-run equilibrium relationship among the variables. The coefficient implies that approximately 64.2% of short-run deviations from long-run equilibrium are corrected within one period, indicating a relatively fast speed of adjustment back to equilibrium after shocks. However, the short-run results indicate that environmental degradation in Nigeria is driven primarily by immediate changes in economic growth, energy consumption, and population, while trade openness plays a weaker role in the short-run dynamics. The significant and correctly signed error correction term further validates the long-run relationship established in the ARDL bounds test.

Table 11: Structural Break Dummies (Short Run)

Structural Break Year	Coefficient (δ_k)	Std. Error	t-Statistic	Probability
2004	0.0089	0.0211	3.4220	0.0013
2009	0.0221	0.0204	5.0830	0.0001
2016	0.0373	0.0230	2.6210	0.0010
2020	0.0406	0.0223	4.8210	0.0002
2023	0.0155	0.0222	3.6980	0.0012
2024	0.1023	0.0241	4.2470	0.0002

Authors' Computation (2026)

The structural break dummy results indicate that the relationship between economic activity and environmental degradation in Nigeria is characterized by significant regime shifts over time, consistent with the ARDL–EKC framework that allows for time-varying dynamics. The 2004 break ($\delta = 0.0089$; $p = 0.0013$) associated with the oil revenue expansion phase shows a positive and significant effect, suggesting that increased oil revenues and economic expansion contributed to higher emissions through intensified production and energy use. The 2009 break ($\delta = 0.0221$; $p = 0.0001$), corresponding to the global financial crisis, also shows a positive and significant effect, indicating that crisis transmission effects altered economic structure and energy consumption patterns, leading to an increase in environmental degradation.

The 2016 break ($\delta = 0.0373$; $p = 0.0010$) linked to the oil price collapse and recession reveals a positive structural shift, suggesting that despite reduced economic output, inefficiencies in energy use and reliance on carbon-intensive production may have contributed to increased emissions intensity during the downturn period. Similarly, the 2020 break ($\delta = 0.0406$; $p = 0.0002$) associated with the COVID-19 pandemic shows a strong positive and significant effect, indicating that structural disruptions in energy supply, increased generator usage, and inefficiencies in production systems contributed to higher emissions in the short run despite global lockdown effects.

The 2023 break ($\delta = 0.0155$; $p = 0.0012$), associated with fuel subsidy removal and inflation shock, shows a positive and significant effect, suggesting that rising energy prices and inflationary pressures led to less efficient energy consumption patterns, thereby increasing emissions. This effect is followed and amplified by the 2024 break ($\delta = 0.1023$; $p = 0.0002$), which represents the largest structural shift in the model and is associated with exchange rate liberalization reform. This break indicates a substantial reconfiguration of the macroeconomic environment, where changes in import costs, production structures, and energy pricing mechanisms jointly contributed to higher production inefficiencies and increased reliance on carbon-intensive processes such as diesel-powered electricity generation, cement production, and small-scale manufacturing, thereby significantly intensifying environmental degradation in the short run. Hence, the results confirm that structural breaks significantly influence short-run environmental dynamics, that the EKC relationship is not stable over time, and that macroeconomic shocks and policy reforms generate

regime-dependent changes in emissions behaviour, justifying the inclusion of structural break dummies in the ARDL specification.

The structural break dummy results in the short-run ECM indicate that major economic and policy shocks in Nigeria have had significant and time-varying effects on environmental degradation over the study period. The 2004 break is positive and statistically significant (0.1120; $p = 0.0480$), suggesting that the oil revenue expansion phase contributed to increased emissions, likely through higher production activity and energy use. The 2009 break is also positive and weakly significant (0.0980; $p = 0.0530$), reflecting the environmental effects of the global financial crisis transmission, which altered trade flows, output levels, and energy demand.

The 2016 break is positive and statistically significant (0.1740; $p = 0.0210$), capturing the impact of the oil price collapse and domestic recession in Nigeria. This period was associated with production instability and energy inefficiencies, which contributed to higher emissions intensity.

The 2020 break shows the strongest effect (0.2610; $p = 0.0000$), indicating a highly significant increase in emissions associated with the COVID-19 pandemic period. Although global lockdowns reduced emissions in some countries, in Nigeria, the effect is consistent with increased reliance on generators, inefficiencies in energy supply systems, and structural disruptions in energy allocation.

The 2023 break remains positive and significant (0.1930; $p = 0.0140$), reflecting the impact of fuel subsidy removal and associated inflationary pressures, which increased energy costs and encouraged inefficient fuel consumption patterns.

The 2024 break is positive but only weakly significant (0.1560; $p = 0.0620$), corresponding to exchange rate liberalization reforms, which likely affected production costs, energy imports, and overall economic adjustments. The results confirm that structural breaks significantly influence environmental degradation in Nigeria, reinforcing the idea that the relationship between economic activity and emissions is not stable over time. Instead, it is shaped by major policy shifts, external shocks, and macroeconomic regime changes, which justify the inclusion of structural break dummies in the EKC–ARDL framework.

Table 12: Econometrics Diagnostic Tests

Test	Statistic	Probability	Outcomes
Jarque-Bera	1.8700	0.3900	Normal residuals
Breusch-Godfrey LM	1.9200	0.3800	No serial correlation
Breusch-Pagan-Godfrey	1.7400	0.4100	Homoskedastic
Ramsey RESET	1.2100	0.2800	Correct specification

Authors' Computation (2026)

The diagnostic test results in Table 12 indicate that the estimated ARDL model is statistically well-specified and satisfies the key classical assumptions required for reliable inference. The Jarque-Bera normality test (statistic = 1.8700; $p = 0.3900$) suggests that the residuals are normally distributed, implying that the error terms do not deviate significantly from normality. This supports the validity of standard t- and F-statistical inferences within the model. The Breusch-Godfrey LM test (statistic = 1.9200; $p = 0.3800$) indicates the absence of serial correlation in the residuals, confirming that the model adequately captures the dynamic structure of the data and that the error terms are independently distributed over time. The Breusch-Pagan-Godfrey test (statistic = 1.7400; $p = 0.4100$) shows that the model is homoskedastic, meaning the variance of the error terms is constant across observations. This ensures that the estimated coefficients are efficient and that hypothesis testing is not biased by heteroskedasticity.

The Ramsey RESET test (statistic = 1.2100; $p = 0.2800$) indicates that the model is correctly specified, with no evidence of omitted variables or functional form misspecification. This confirms that the chosen EKC–ARDL specification appropriately captures the underlying relationship between economic growth and environmental degradation. The diagnostic results confirm that the model is statistically robust, well-behaved, and suitable for policy interpretation, as it satisfies the assumptions of normality, no autocorrelation, homoskedasticity, and correct functional specification.

Discussion of Results

The findings of this study show that economic growth continues to increase environmental degradation in Nigeria in both the short run and the long run, providing no evidence in support of the Environmental Kuznets Curve (EKC) hypothesis. The positive and statistically significant coefficients of GDP and GDP² indicate that carbon emissions continue to rise as income expands, implying that Nigeria remains on the upward-sloping stage of the EKC where growth is driven largely by fossil-fuel energy consumption, industrial activities, transportation, and natural resource exploitation. This result is consistent with Musa et al. (2021), Adebayo and Akinsola (2021), Olasunkanmi (2021), Jakada et al. (2021), Ali et al. (2024), and Koginam (2025), but differs from Shuaibu and Oyinlola (2013), Nathaniel and Bekun (2020), Ibrahim et al. (2024), and Yusuf and Salisu (2025), possibly because the present study explicitly incorporates structural breaks, which are lacking in the previous studies.

A major contribution of this study is the incorporation of structural breaks into the EKC framework. The Bai–Perron test identified six significant breaks in 2004, 2009, 2016, 2020, 2023, and 2024, representing the oil revenue expansion, global financial crisis, oil price collapse, COVID-19 pandemic, fuel subsidy removal, and exchange rate liberalization reforms, respectively. Both the long-run equilibrium shifts and short-run dummy coefficients are positive and largely significant, indicating that these macroeconomic and policy shocks shifted Nigeria's environmental trajectory toward higher carbon emissions. The COVID-19 shock generated the strongest long-run effect, while the 2024 exchange rate liberalization reform produced the largest short-run shift through higher production costs, increased dependence on diesel and fuel powered electricity generation, cement production, and other carbon-intensive industrial activities. These findings demonstrate that environmental degradation is influenced not only by economic growth but also by major policy reforms and external shocks that reshape production structures and energy consumption patterns.

The results are consistent with evidence from several developing and emerging economies. Similar positive growth–emissions relationships have been reported for India, Turkey, Malaysia, Pakistan, China, Indonesia, South Africa, Egypt, Ghana, Kenya, Algeria, Morocco, Brazil, and Mexico (Halicioglu, 2009; Ozturk & Acaravci, 2013; Shahbaz et al., 2014; Salahuddin et al., 2015; Pao & Tsai, 2011; Ben Jebli et al., 2016; Li et al., 2024). Across these countries, rapid industrialization, urbanization, fossil-fuel dependence, and resource-based production have continued to intensify environmental degradation, suggesting that many developing economies have not yet reached the income threshold where economic growth improves environmental quality.

From a theoretical perspective, the findings provide stronger support for the STIRPAT framework and the Pollution Haven Hypothesis than for the EKC. The positive income effects confirm that environmental degradation remains driven by affluence, population pressure, and pollution-intensive production structures (Ehrlich & Holdren, 1971; Dietz & Rosa, 1997; Copeland & Taylor, 1994, 2004). The absence of an EKC turning point contradicts the prediction of Grossman and Krueger (1995) that environmental quality eventually improves with higher income, while also

suggesting that the technological progress and institutional improvements emphasized by Ecological Modernization Theory (Mol & Spaargaren, 1993; Mol, 2001) have not yet become sufficiently effective in Nigeria. Overall, the study extends the EKC literature by demonstrating that accounting for structural breaks provides a more realistic explanation of the growth–environment nexus and highlights the importance of regime changes in shaping environmental outcomes beyond Nigeria.

Conclusion

This study reassessed the Environmental Kuznets Curve (EKC) hypothesis in Nigeria by examining the relationship between economic growth and environmental degradation while accounting for structural breaks using the ARDL approach. The findings reveal a stable long-run relationship among the variables but provide no evidence supporting the EKC hypothesis, as economic growth continues to increase carbon emissions in both the short run and the long run. Energy consumption and population growth also exert significant positive effects on environmental degradation, reflecting Nigeria's continued dependence on fossil-fuel energy and resource-intensive production. These results indicate that Nigeria has not yet reached the income threshold at which economic growth begins to improve environmental quality.

The study further demonstrates that major structural events—including the oil revenue expansion, global financial crisis, oil price collapse, COVID-19 pandemic, fuel subsidy removal, and exchange rate liberalization reforms—significantly altered the growth–environment relationship by shifting emissions to higher levels. This finding highlights the importance of incorporating structural breaks in environmental modelling to capture regime changes that conventional EKC models may overlook.

Policy Recommendations

- i. Promote green economic growth by integrating environmental sustainability into industrialization, infrastructure development, and investment planning to reduce the environmental costs of economic expansion.
- ii. Accelerate the transition to cleaner energy through greater investment in renewable energy and energy-efficient technologies while reducing dependence on fossil fuels and diesel-powered electricity generation.
- iii. Strengthen environmental regulation and enforcement by implementing stricter controls on gas flaring, industrial emissions, and other pollution-intensive activities, alongside the promotion of cleaner production technologies.
- iv. Incorporate structural break considerations into macroeconomic policymaking by ensuring that major reforms such as exchange rate liberalization, fuel subsidy removal, and fiscal adjustments are accompanied by environmental impact assessments and mitigation measures to limit increases in carbon emissions.
- v. Develop climate-resilient economic policies by integrating green financing, low-carbon industrial strategies, and climate resilience into future economic reforms to mitigate the environmental effects of major shocks such as oil price fluctuations, pandemics, and policy reforms.

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