Innovations

Economic Growth, Urbanization and CO_2 Emissions in Nigeria: Evidence from the Environmental Kuznets Curve

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Abstract: *This study examines the relationship between economic growth, urbanization, trade openness, FDI, energy consumption, and CO_2 emissions in Nigeria from 1971 to 2020. The study confirms the Environmental Kuznets Curve (EKC) hypothesis for Nigeria, demonstrating a substantial positive correlation between GDP per capita and CO_2 emissions using robust econometric methods. Increasing GDP per capita by 1% results in a 0.597% increase in emissions, where as urbanization contributes an additional 1.39%. Similarly, trade openness and FDI increase emissions by 0.676% and 0.356%. The most significant impact is energy use, which decreases environmental quality by 4.72% every 1%. Domestic capital movements had no substantial effect on emissions, prompting additional research. Short- and long-run estimates corroborate the EKC hypothesis, especially in the transport sector, where income growth first increases emissions but later favors cleaner technologies. Renewable energy, efficient urban design, and sustainable industrial practices are crucial for striking a balance between economic growth and environmental sustainability.*

Keywords: *Environmental Kuznets Curve; CO_2 emissions; Economic growth; Energy consumption; Urbanization; Nigeria*

Introduction

The interplay between environmental sustainability and economic growth has remained a central and pressing issue in development research, particularly in light of the global concerns about climate change. The primary cause of environmental degradation and global warming is widely acknowledged to be carbon dioxide (CO_2) emissions, which constitute the most significant proportion of greenhouse gases (IPCC, 2022). The challenge for developing economies is to strike a balance between the need for rapid economic development and the imperative to preserve environmental quality. This dilemma is especially evident in Nigeria, where the environmental stress is being exacerbated by industrialization, energy dependence on fossil fuels, and urban expansion.

The Environmental Kuznets Curve (EKC) hypothesis offers a valuable framework for investigating this dynamic. It posits that environmental degradation initially increases with rising income levels as a result of industrialization and energy consumption. However, it eventually declines after a certain income threshold is reached, as economies transition towards cleaner technologies, improved efficiency, and stronger environmental regulation (Grossman & Krueger, 1995; Stern, 2004). Although the EKC has been validated in numerous developed and emerging economies (Jalil & Mahmud, 2009; Bölük & Mert, 2015; Bibi & Jamil, 2021), the results from Sub-Saharan Africa are still inconclusive. In Nigeria, the EKC hypothesis is supported by certain studies (Omisakin, 2009; Maduka et al., 2022), while others refute it (Ogundipe et al., 2014; Onifade, 2022). This differentiation highlights the need for current empirical evidence to encompass the more comprehensive economic and structural dynamics that influence emissions. Nigeria presents a critical case for examining the EKC.

Nigeria, the most populous nation and largest economy in Africa, has experienced rapid development as a result of trade liberalization, oil exports, and foreign direct investment (FDI). Nevertheless, these advancements have been accompanied by an increase in CO_2 emissions. The country's energy consumption, transportation demand, and industrial activity have substantially increased as a result of the country's accelerating urbanization, limited adoption of renewable energy, and reliance on fossil fuels, which have increased by an average of over 4% annually. The pressure on Nigeria's environment is not the only thing that these structural patterns intensify; they also undermine the country's commitment to international agreements, such as the Paris Accord, which mandates substantial reductions in greenhouse gas emissions by 2030. Nigeria's capacity to fulfil these obligations may be considerably affected by the results of this investigation. The literature on the growth–environment nexus in Nigeria is still fragmented, despite its significance. Over an extended historical period, few studies have simultaneously considered the impact of economic growth, urbanization, trade liberalization, FDI, and energy consumption.

Nevertheless, this investigation employs a thorough methodology, which encompasses all of these variables and more. Additionally, Nigeria's carbon profile is frequently overlooked due to sector-specific factors, including transportation-related emissions, which are of paramount importance. This discrepancy limits policymakers' ability to develop effective strategies that balance environmental sustainability with development objectives. This study, therefore, examines the short-run and long-run correlations stuck between economic growth, urbanization, trade openness, FDI, energy consumption, and CO_2 emissions in Nigeria from 1971 to 2020. The primary goal is to evaluate the validity of the EKC hypothesis in the Nigerian context and to investigate the sectoral impact of transport emissions. The study enquires explicitly whether Nigeria's economic growth adheres to the inverted U-shaped EKC trajectory.

The study makes numerous substantial contributions by addressing these concerns. It provides new evidence on the applicability of the EKC hypothesis in a significant Sub-Saharan African economy, employing an expanded dataset and supplementary explanatory variables. This empirical study provides one of the most comprehensive analyses of Nigeria's growth–environment nexus to date, emphasizing both aggregate and sectoral dynamics. It is anticipated that the results will be of significant interest to Nigeria's policymakers, particularly in terms of strategies for aligning economic development with commitments to climate change.

This will be achieved through the implementation of sustainable energy policies, urban planning, and low-carbon investment. In doing so, the research contributes to the broader conversation about how developing economies can achieve growth without compromising environmental integrity.

Review of Related Literature

Numerous research investigations have been conducted in domains relevant to this study. The primary focus of the research conducted was either the linkage between economic growth and the environment or the relationship among economic growth, urbanization, and CO_2 emissions. The literature assessment indicates that limited research has specifically investigated the influence of economic expansion on CO_2 emissions, especially in Nigeria. This literature review will provide a comprehensive examination of the existing research on the interplay between economic growth, urbanization, and CO_2 emissions, initially from a broad perspective and subsequently focusing on Nigeria. The literature review will adopt a dual approach, emphasizing the depth of the analysis. The literature review comprises two components. The initial strand comprises an extensive examination of pertinent studies, while the subsequent strand provides an in-depth analysis of these studies, focusing specifically on Nigeria.

Starting with the first strand, Grossman and Krueger (1991) the investigation of the interconnection between economic growth and environment nexus. Grossman & Krueger (1991) study was shown using cross-country panel data across cities and countries from the Global Environmental Monitoring System. The study Found evidence that concentrations of several local air pollutants initially rise with per-capita income, but after reaching a certain turning point, begin to decline. Therefore, the suggested that economic growth alone may not indefinitely worsen environmental quality; after a certain income threshold, structural changes (shift to services), increased demand for environmental quality, and technological improvements contribute to reductions in pollution. To investigate the linkage and/or causality between fossil fuel energy consumption, trade openness, economic growth, urbanization, foreign direct investment, and CO_2 emissions in various nations and regions worldwide, several empirical studies with diverse methodologies have been conducted.

Some research concentrated on single-country studies to account for the diverse nature of countries, although data on the EKC is inconsistent. For example, Iwata et al. (2010) used ARDL to support the EKC hypothesis for France from 1960 to 2003. Pao & Tsai (2011) found that the correlation between economic growth and CO_2 emissions follows an inverted U-shaped pattern in Brazil from 1980 to 2007. Similar results were observed by Yavuz (2014) for Turkey over 1960-2007 and Boutabba (2014) for India over 1971-2008. According to differing findings from the USA by Millimet & Stengos (2003) and Austria by Friedl & Getzner (2003), there is an N-shaped pattern in the association between environmental deterioration and economic growth.

However, Sarkodie & Strezov (2019) have some qualms about the EKC theory being tested in five developing nations. Their research discovered that a U-shape pattern exists in India and South Africa. Jebli et al., (2016) validated the EKC hypothesis using completely modified OLS and dynamic OLS for OECD countries from 1980 to 2010. Similarly, Churchill et al. (2018) found that economic growth was a long-run remedy for environmental degradation in OECD countries from 1870 to 2014. However, Moutinho et al., (2017) and Zarzoso & Marancho (2004) discovered that the linkage between economic growth and the environment followed an N-shaped pattern when they examined the same OECD countries from 1975 to 1998 using pooled mean group data. Recent research by Balsalobre-Lorente et al., (2018) for Europe over 1985-2016 and Halkos & Polemis (2017) for the OECD over 1970-2014 verify this. Despite these works' efforts to categorize nations according to their degree of economic development, they have failed to consider the regional differences among the nations. For instance, some areas are desert, some are tropical forests, and even the global climate varies, all of which may impact the state of the environment. Therefore, studies that capture regional features are necessary to provide a more comprehensive understanding of the relationship between economic growth and environmental degradation.

Tenaw & Beyene (2021), alongside Bibi & Jamil (2021), contribute to the investigation of the interplay between environmental factors and economic growth. Their collaborative research, which includes the analysis of 20 Sub-Saharan African countries from 1990-2015 and the exploration of the connection between air pollution and economic growth across six global regions from 2000 to 2018, is a testament to the collective effort in this field. The conclusion, that all other regions except for the Sub-Saharan Africa region support the Environmental Kuznets Curve (EKC) hypothesis, underscores the importance of collaboration in advancing our understanding of this complex relationship. Xing et al., (2023) investigate the impact of economic growth on environmental degradation in developing economies using the panel Auto-Regressive Distributed Lag (ARDL) and Pooled Mean Group (PMG) approaches of dynamic panel data regression from Asian economies between 1990 and 2019. The findings indicate the existence of an inverted U form. These findings have important policy implications, suggesting that policies aimed at promoting economic growth should also consider the potential environmental costs. Acheampong & Opoku (2023) investigate whether the rise in environmental deterioration is linked to economic growth. It also investigates the potential mechanisms for environmental degradation to impact economic growth. The findings show that environmental deterioration hurts economic growth using a worldwide panel of 140 nations from 1980 to 2021 and the two-step dynamic system-generalized approach of moment technique to limit endogeneity.

The subsequent component of the literature review concentrations on studies that have examined the correlation between economic growth, energy consumption, and CO_2 emissions in Nigeria. After establishing a positive correlation between the two, Chindo et al. (2015) found that GDP growth in Nigeria is a function of CO_2 emissions, as determined by the ARDL model. Additionally, Sulaiman (2014) demonstrated that CO_2 emissions in Nigeria promote economic growth, and energy consumption elevates CO_2 emissions, suggesting a two-way causality exists between energy consumption and economic growth, as confirmed by the Toda and Yamamoto causality test. Akpan & Chuku (2011) use an autoregressive distributed lag (ARDL) framework to study the correlation between economic growth and environmental degradation in Nigeria from 1960 to 2008. The results suggest an N-shaped connection exemplifies Nigeria's predicament when confronted with facts, highlighting the urgent need for policy changes.

Akorede & Afroz (2020) investigate the linkage between Urbanization, CO_2 emissions, economic growth and energy consumption in Nigeria using the ARDL and Granger causality techniques for the period of 1960 to 2020. The study found that energy consumption & GDP growth have positive significant impact on CO_2 emissions both in short- run and long-run estimation while urbanization shows mixed (negative) effects in some estimations (long-run).Akujor et al., (2023)concluded that the Nigerian transport sector is severelyreliant on fossil fuels energy, and there are possibilities with adoption of alternative energy carriers (natural gas, renewables) and changes in vehicle power train technologies to mitigate CO_2 emissions.

Akinpelumi et al., (2024) investigate asymmetric effect of financial development and urbanization on the environment: Evidence from Nigeria using nonlinear ARDL (NARDL) to capture asymmetries in financial development, urbanization, and economic growth between the period of 1986–2022. The study found that Urbanization, RGDP, financial development has asymmetric effects on ecological footprint. EKC hypothesis supported both in short- and long-run in this context. Nadabo & Salisu, (2025) also examined testing the validity of the EKC hypothesis using CO_2 emissions and ecological footprint in Nigeria between 1991–2022 using ARDL bounds test and Toda-Yamamoto causality techniques. The study concluded that economic growth positively correlates with both CO_2 emissions and ecological footprint; EKC effects emerging but environmental degradation rises with growth.

Conclusively, many Nigerian studies either focus on trade/FDI or growth, or urbanization, but seldom combine all key drivers (GDP per capita & its square, urbanization, trade openness, FDI, energy consumption) in both short-run and long-run analysis over an extended time frame (1971–2020).Then transportation sector emissions, energy mix (renewables vs non-renewables), and urban infrastructure effects are often insufficiently disaggregated. Many studies treat energy consumption as aggregate rather than breaking it into constituents. Meanwhile, some studies omit the square of GDP per capita (which is essential for EKC shape). Urbanization is often proxied simply by urban population level, not growth rate. This study aims to fill a gap by exploring the issue in detail and finding effective improvements, using a long time series (1971–2020) that covers enough decades to detect EKC turning points. More so, including all major drivers: income per capita plus square, urbanization growth (not just level), trade openness, FDI, energy consumption, possibly with transport sector emissions when data allows. Disaggregating energy consumption and examining sectoral emissions.

Methodology and Data

This study employs a quantitative research design, employing time-series econometric methods, to thoroughly examine the vigorous linkage stuck between economic growth and environmental quality in Nigeria. The Autoregressive Distributed Lag (ARDL) bounds testing approach is picked for its efficiency with lesser sample sizes and its capacity to capture both short-run and long-run relationships. While prior studies often focused on models with only three variables typically economic growth, urban population, and environmental quality some have included human capital as a control. More recent research, such as that by Chindo et al. (2015), has emphasized the significance of incorporating energy consumption and fossil fuel use into growth models to understand their impact better. Annual Data 1971–2020: CO_2 (metric tons / per capita and total) from World Bank WDI use both for robustness GDP per capita (constant USD), urban population (% of total), energy consumption (kg oil eq per capita or total), industrial value-added (% GDP), trade openness, population annual population growth rate.

This study builds on the EKC framework by adapting some environmental model used in previous works by Jaunky (2011), Ghosh and Kanjilal (2014), Salahuddin et al. (2015), Ahmed et al. (2015), and Abbasi et al. (2021), with some modifications. Key revisions include the incorporation of urbanization to capture urban population growth and the addition of fossil fuel energy consumption as a critical factor. GDP per capita is used to represent economic growth, whereas trade openness reflecting imports and exports is included as a control variable due to its influence on environmental degradation.

Here, we assume the following utility function provides the representative agent preferences to establish a general framework for comprehensively and succinctly analyzing the existing EKC theoretical literature.

$$U = U(C, P) \qquad (1)$$

U (·) is affected by consumption C and pollution P. It increases in C and decreases in P, and it is assumed in both arguments to be strictly concave.

Baseline model (log form)

$\ln(CO_{2t}) = \alpha + \beta 1 \ln(GDPpc_t) + \beta 2 \ln(GDPpc_t)^2 + \gamma \ln(Urb_t) + \delta X_t + \varepsilon_t$(2)

where CO_{2t}(carbon dioxide emissions), GDPpc (gross domestic products per capita), Urb is urbanization (% or urban population), X are controls (energy use, industry share, trade).

Consequently, this current study presents a comprehensive model derived from equation 1. These equations, which cover various aspects of urban population growth, economic growth and energy consumption, trade openness, and foreign direct investment form the basis of our empirical investigation.

$$CO_{2t} = f(Y_t, Y^2{}_t, UB_t, EN_t, FF_t, TR_t, FD_t) \quad (3)$$

Equation 3 is transformed into a log form, and then the next econometric model is used to standardize the model and with the following logging the variable produces:

$$\ln CO_{2t} = \alpha_0 + \alpha_1 \ln Y_t + \alpha_2 Y^2{}_t + \alpha_3 \ln UB_t + \alpha_4 \ln EN_t + \alpha_5 \ln FF_t + \alpha_6 \ln TR_t + \ln FD_t + \varepsilon_t \quad (4)$$

We expect that the coefficient $\alpha_1, \alpha_2, \alpha_3, \alpha_4,\ \alpha_5,\ and\ \alpha_6 > 0$. however, if higher levels of urbanization as well as higher levels of energy consumption mitigate environmental degradation, then $\alpha_2, \alpha_6 < 0$.

It is imperative to evaluate the cogency of the long-run model's represented by equation (3) to evaluate the variables' co-integration. The Unrestricted Error-Correction Model (UECM) is a critical element of this process, as it is specifically engineered to evaluate the cointegration of the long-run model (Ghosh & Kanjilal, 2014; Chindo et al., 2015; Maji et al., 2019; Abbasi et al., 2021). The focus of this current investigation is on the expansion of economic growth, which sets it apart from previous research. The subsequent content will provide a more comprehensive examination of the UECM, emphasizing its significance in our investigation.

$$\Delta \ln CO_{2t} = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta \ln CO_{2t-i} + \sum_{i=0}^{n} \alpha_{2i} \Delta \ln Y_{t-i} + \sum_{i=0}^{n} \alpha_{3i} \Delta Y^2{}_{t-i} + \sum_{i=0}^{n} \alpha_{4i} \Delta \ln UB_{t-i}$$
$$+ \sum_{i=0}^{n} \alpha_{5i} \Delta \ln EN_{t-i} + \sum_{i=0}^{n} \alpha_{6i} \Delta \ln FF_{t-i} + \sum_{i=0}^{n} \alpha_{7i} \Delta \ln TR_{t-i} + \sum_{i=0}^{n} \alpha_{8i} \Delta \ln FD_{t-i} + \tau_1 \ln CO_{2t-1} + \quad (5)$$
$$\tau_2 \ln Y_{t-1} + \tau_3 Y^2{}_{t-1} + \tau_4 \ln UB_{t-1} + \tau_5 \ln EN_{t-1} + \tau_6 \ln FF_{t-1} + \tau_7 \ln TR_{t-1} + \tau_8 \ln FD_{t-1} + \mu$$

From equation (4), then, we can descend the long-run co-efficient as follows:

$$\tau_1 = \frac{1}{\tau_1}, \tau_2 = \frac{-\tau 2}{\tau_1}, \tau_3 = \frac{-\tau_3}{\tau_1}, \tau_4 = \frac{-\tau_4}{\tau_1}, \tau_5 = \frac{-\tau_5}{\tau_1} = \frac{-\tau_6}{\tau_1} \quad (6)$$

In this model, Δ it represents the first difference operator. The variables are expressed in natural logarithms as follows: $CO_{2\,t}$ denotes the ecological footprint, Y_t is GDP per capita, and Y_{2t} represents the square of GDP per capita to capture potential nonlinear effects. UB_t stands for urban population growth, EN_t for energy consumption, and FF_t for fossil fuel consumption. TR_t reflects trade openness, while FD_t represents foreign direct investment. The model also includes an error correction term to account for long-run equilibrium adjustments.

Then, to determine the cointegration test for the variables' in model's (4), therefore this investigation should run the Wald coefficient test to obtain the F-statistic after equation. $\tau 1=\tau 2=\tau 3=\tau 4=\tau 5=\tau 6=\tau 7=0$. When there is a long-run correlation among variables', the F test checking indicates that the variables are normalized. Following that, the study must compare F-statistics to the critical values of Narayan's bounds test (2005).

$$\Delta \ln CO_{2t}=\alpha_0+\sum_{i=1}^{n-1}\alpha_{1i}\Delta \ln CO_{2t-i}+\sum_{i=0}^{n-1}\alpha_{2i}\Delta \ln Y_{t-i}+\sum_{i=0}^{n-1}\alpha_{3i}\Delta Y^2{}_{t-i}+\sum_{i=0}^{n-1}\alpha_{4i}\Delta \ln UB_{t-i}+ \sum_{i=0}^{n-1}\alpha_{5i}\Delta \ln EN_{t-i}+\sum_{i=0}^{n-1}\alpha_{6i}\Delta \ln FF_{t-i}+\sum_{i=0}^{n-1}\alpha_{7}\Delta \ln TR_{t-i}+\sum_{i=0}^{n-1}\alpha_{8}\Delta \ln FD_{t-i}+\delta ECT_{t-1}+\varepsilon_t \quad (7)$$

Where error correction term ect_{t-1} can be expressed as:

$$ect_{t-1}=\delta_{t-1}=CO_{2t-1}-(\alpha_0+\alpha_1 \ln CO_{2t-1}+\alpha_2 \ln Y_{t-1}+\alpha_3 Y^2{}_{t-1}+\alpha_4 \ln UB_{t-1}+ \alpha_5 EN_{t-1}+\alpha_6 FF_{t-1}+\alpha_7 TR_{t-1}+\alpha_8 FD_{t-1}) \quad (7)$$

In this context, Δ represents the first difference operator, while denotes the co-efficient of the error-correction term, which quantifies the rate of adjustment towards long-run symmetry. If the relationship remains negative then statistically momentous, co-integration is present. Then, the study's first estimates the F-statistics and liken them with the upper bound critical values' from the Narayan (2005) table to assess co-integration. Thus, co-integration is confirmed after the F-statistic surpasses the upper bounds, while it is deemed absent if it is below the lower bound critical values' as specified by Narayan's. The results are indeterminate when the F-statistics fall between the upper and lower bounds'. The null hypothesis for assessing co-integration is designated as per Ho $\tau_1=\tau_2=\tau_3=\tau_4=\tau_5=\tau_6=\tau_7=0$ .While the alternative hypothesis is denoted as H1: $\tau_1 \neq \tau_2 \neq \tau_3 \neq \tau_4 \neq \tau_5 \neq \tau_6 \neq \tau_7 \neq 0$ whereas, ECT_{t-1} is the error-correction model is important as it illustrates a long-run correlation stuck between the dependent and independent variables'. The values of the error-correction models are obtained from the estimation of long-run co-efficient.

Result and Discussion

This section investigates the correlation amid-between economic growth and environmental quality's in Nigeria as one of the emerging economy, aiming on patterns of ecological changes across different income levels. Does earlier economic growth and urbanization effect in the buildup of natural capital or the depletion of natural resource reserves? In Nigeria, there is concern that economic progress would lead to environmental damage. However, it's crucial to understand that strategic planning and adopting sustainable practices are not just hopeful measures, but urgent ones, as they facilitate the balance of expansion and environmental protection, a balance that Nigeria must strive to achieve.

The discussion of this segment's findings began with a rigorous pre-test to determine the variables' stationarity. We used the augmented Dickey-Fuller (1981) and Phillips-Perron (1988) unit root tests, which are commonly used. A variable is stationary if its mean, variance, and covariance linger constant. This thorough method is critical for assessing the series' integration degree and preventing incorrect results. Our empirical ARDL paradigm likewise removes I(2) series inclusion, leaving just I(0), I(1), or a combination.

The outcomes of unit-root test are summarized in Table's 1. This shows that all the considered variables' are categorized as I(1) because they exhibit stationarity at the first difference. The null hypothesis concerning the unit-root problem was not rejected in its level form; however, the initial differences demonstrate significance at the 1% level for all variables. The outcomes of this investigation have a significant to real-world insinuations, offering valuable insights into the link stuck between Nigeria's economic growth and ecological quality.

Table 1 Results of the Unit Root Test

Level Variables	**ADF**		**PP**	
	Constant	**Constant with Trend**	**Constant**	**Constant with Trend**
$lnCO_{2t}$	2.258 (0.999)	0.984 (0.999)	2.085 (0.999)	0.8453 (0.999)
lnY_t	-0.807 0.808)	-1.378 (0.855)	-0.975 (0.755)	-1.211 (0.897)
Y^2_t	-0.538 (0.874)	-1.245 (0.889)	-0.825 (0.803)	-1.203 (0.899)
$lnUB_t$	-2.444 (0.135)	-2.444 (1.135)	-2.567 (0.107)	-2.837 (0.192)
$lnEN_t$	-2.448 (0.134)	-2.415 (0.367)	-2.754 (0.072)	-2.371 (0.389)
$lnFF_t$	-5.798 (0.000)***	-4.448 (0.04)***	-5.569 (0.00)***	-4.553 (0.000)***
$lnTR_t$	-2.367 (0.156)	-2.345 (0.402)	-2.597 (0.100)	-2.603 (0.281)
$lnFD_t$	-3.397 (0.016)**	-3.354 (0.070)*	-3.194 (0.026)**	-3.1435 (0.108)
$lnCF_t$	-2.239 (0.195)	-2.9723 (0.150)	-2.056 (0.262)	-2.972 (0.150)

First Difference				
$lnCO_{2t}$	-4.933 (0.002)***	-5.524 (0.002)***	-4.8799 (0.002)***	-5.5313 (0.00)***
lnY_t	-2.252 (0.191)	-2.475 (0.338)	-5.3824 (0.000)***	-5.5131 (0.002)***
Y^2_t	-5.623 (0.000)***	-5.835 (0.001)***	-5.828 (0.000)***	-5.907 (0.000)***
$lnUB_t$	-6.589 (0.000)***	-6.840 (0.000)***	-6.5892 (0.000)***	-6.8408 (0.000)***
$lnEN_t$	-6.141 (0.000)***	-6.391 (0.000)***	-6.0951 (0.000)***	-6.5653 (0.000)***
$lnFF_t$	-4.958 (0.002)***	-5.524 (0.002)***	-4.9106 (0.000)***	-5.4881 (0.000)***
$lnTR_t$	-7.460 (0.000)***	-7.379 (0.000)***	-7.4367 (0.000)***	-7.3612 (0.000)***
$lnFD_t$	-10.744 (0.000)***	-10.632 (0.000)***	-10.8072 (0.000)***	-10.8291 (0.000)***
$lnCF_t$	-7.3069 (0.000)***	-5.231 (0.005)***	-9.1606 (0.000)***	-9.0067 (0.000)***

Note: ***, **, * indicate significance level at 1%, 5% and 10% respectively. Values in parenthesis are probability value

The Zivot-Andrews (1992) structural break unit-root test, which accounts for trend breaks, played a key role in reducing uncertainty in unit-root investigation. The outcomes of this investigation, shown in Table's 2, are significant because they show that all variables display stationarity in their initial difference form while remaining nonstationary in the level form. This significant finding, which validates the usage of the ARDL approach, emphasizes the value of the Zivot-Andrews test.

Table 2: Zivot-Andrews Unit-Root Test Results

Level					First Difference				
Variables	Constant	Break point	Constant & trend	Break point	Constant	Break point	Constant & trend	Break point	Inference
$lnCO_{2t}$	-1.149	2013	-1.232	2013	-7.461***	2009	-7.358***	2009	I(1)
lnY_t	-2.327	2007	-4.846*	1981	-6.204	1984	-9.435**	2016	I(I)

							*		
Y^2_t	-2.286	2002	-4.281	1981	-6.310***	1982	-6.784***	2016	I(I)
$lnUB_t$	-4.022	1992	-4.849*	1992	-8.751***	1993	-9.047***	1993	I(I)
$lnEN_t$	-3.333	1999	-3.046	1975	-7.108***	1994	-7.333***	1994	I(I)
$lnFF_t$	-.665***	2010	-5.242**	1975	-7.156***	1982	-7.087***	1982	I(I)
$lnTR_t$	-4.459**	1995	-4.847*	1995	-8.274***	1982	-8.141	1982	I(I)
$lnFD_t$	-3.798	2015	-4.411	1989	11.973***	1996	11.978***	1996	I(I)
$lnCF_t$	-4.931**	2006	-4.880**	2006	-8.097***	1981	-7.944***	1981	I(I)

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Upon confirming stationarity, descriptive statistics, and a correlation matrix were used for the variables', with the findings presented in Table's 3. The Jarque-Bera test demonstrated that all variables conform to a normal distribution. The correlation analysis, a crucial aspect of our investigation, shows the strength and path of the link among the variables'. The correlation analysis of the key variables revealed a robust and concerning link among economic growth and environmental quality, particularly regarding the ecological footprint. This discovery highlights the gravity of the situation; as economic growth is intricately connected to environmental consequences. Therefore, the regulator variables prove a varied and significant relationship. An alarming inverse correlation exists between fossil fuel energy consumption and foreign direct investment in ecological quality, highlighting the need for a shift in investment strategies to address the gravity of the situation.

Table's 3: Descriptive Statistics and Correlation Matrix

	$lnCO_{2t}$	lnY_t	Y^2_t	$lnUB_t$	$lnEN_t$	$lnFF_t$	$lnTR_t$	$lnFD_t$	$lnCF_t$
Mean	3.790	7.528	3809889	1.547	6.553	2.857	3.407	0.157	2.145
Median	3.859	7.538	3527450	1.557	6.551	2.942	3.532	0.201	2.100
Maximum	4.031	7.897	7226781	1.766	6.683	3.129	3.975	1.756	2.977
Minimum	2.998	7.236	1928029	1.292	6.361	1.786	2.212	-1.634	1.547
Std. Dev.	0.230	0.224	1700948	0.119	0.081	0.291	0.465	0.774	0.348
Skewness	-1.790	0.138	0.532	0.017	-0.636	-2.289	-1.193	-0.241	0.382
Kurtosis	5.899	1.562	1.971	2.307	2.734	7.611	3.604	2.611	2.447
Jarque-Bera	43.334	4.379	4.475	0.983	3.445	86.218	12.362	0.785	1.819
Probability	0	0.112	0.107	0.612	0.179	0	0.002	0.675	0.402
lnCO2t	1								
lnY_t	-0.307	1							
Y^2_t	-0.399	0.986	1						
$lnUB_t$	0.295	-0.131	-0.136	1					
$lnEN_t$	-0.046	0.297	0.366	0.094	1				
$lnFF_t$	0.186	-0.190	-0.124	0.453	0.745	1			
$lnTR_t$	0.168	0.294	0.248	-0.428	0.231	0.006	1		
$lnFD_t$	0.162	-0.011	-0.068	-0.309	-0.062	-0.291	0.456	1	
$lnCF_t$	-0.068	0.658	0.671	-0.106	0.600	0.239	0.404	0.019	1

Utilize the Schwarz Information Criterion (SIC) to select the most suitable fit and intricacy model for determining the optimal lag period in a cointegration test. The SIC signifies a more conservative approach, imposing stricter penalties on models with additional parameters (lags) than the Akaike Information Criterion (AIC). The optimal choice is typically the lag length corresponding to the lowest SIC value. This serves as a general guideline; however, the suitable lag length will differ based on the investigation context and the specific data set utilized.

Before we could commence our exploration of the cointegration correlation between the variables in our study, we primary had to decide the appropriate lag period. Cointegration, a statistical property of a set of time series variables, indicates a common stochastic trend and is a valuable tool for analyzing long-run relationships in economic data. With our limited time series data, the choice of lag length, m, is a delicate balance. It must be small enough to avoid over parameterization yet large enough to handle concerns about residual serial correlation. This selection assumes the error term, **ωt**, is serially independent (Pesaran et al., 2001, p. 308). The ideal lag time was determined using the Schwarz information criterion (SIC), as presented in Table's 4, highlighting the complexity and precision of our research process.

Table 4 Lag Length Selection for Cointegration Analysis Based on SIC

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-104.669	NA	1.600	5.287	5.655	5.422
1	239.062	527.588	8.520	-6.933	-3.247*	-5.573
2	327.880	99.145	9.870	-7.297	-0.293	-4.714
3	484.941	109.577 *	1.540*	- 10.834*	-0.513	-7.028*

Note: LR = sequential modified likelihood ratio; FPE = final prediction error; AIC = Akaike Information Criterion; SC = Schwarz Criterion; LogL = log-likelihood. *Indicates lag length selected by each criterion.

Following the implementation of unit root and descriptive statistics tests, the cointegration method remained used to analyze the long-run correlation amongst the study variables'. Thus, the investigation used the autoregressive distributed lags approach to appraise and analyze the cointegration of the constraints identified by Pesaran et al. (1998). Accurate lag length selection is vital before implementing the ARDL cointegration analysis. The lag interval was meticulously evaluated, as an incorrect selection could result in biased outcomes and is unsuitable for action-oriented research. The research utilized the Akaike information criterion (AIC) to determine the suitable lag duration, thereby enabling the identification of relevant lag intervals. The AIC norm produces results comparable to the Schwartz Bayesian criterion (SBC). Table's 5 present the outcomes of the ARDL bounds test for co-integration.

Table Fehler! Kein Text mit angegebener Formatvorlage im Dokument.**: ARDL Bounds Test for Cointegration**

Bounds test critical values					
[Unrestricted intercept & no trend]					
	FStats (p value)	Lag	Level of significance	I(0)	I (1)
Model 1					
f($\ln CO_{2t}$, $\ln Y_t$, Y^2_t, $\ln UB_t$, ln EN ln FF_t $\ln TR_t$, $\ln FD_t$)	9.747	4, 3, 1, 4, 4, 4, 4, 4	10 %	2.238	3.461
			5 %	2.643	4.004
			1 %	3.595	5.225

Note: Critical bounds are drawn from Narayan (2005), Case III. Bolded values indicate the significance levels and bounds confirming the presence of cointegration.

The critical value ranges for F-statistics is 25.702 at the 1% significance level. Once the values have been assessed, they continue to be pertinent for evaluating a relationship between the two cointegration connections. The initial two long-run relationships indicate scenarios where lnCO2t emissions are the dependent variables, with economic growth as the principal variable in the model examined in this study. The study employed the Johansen and Juselius test to assess the robustness of the autoregressive distributed lags bounds check approach for the long-run relationship. This test is recognized for its robust and reliable multivariate cointegration methodology, instilling confidence in the research findings.

Estimation Results

The outcomes of the analysis regarding the impact of economic growth on Nigeria's environmental quality from 1971 to 2020 are presented in the tables below. The validation checks of ordinary least squares are significant and positive. The modified coefficients of the determinant indicate that the research variables considered in model is carbon dioxide emissions from the sectorial ($lnCO_2t$). Furthermore, the results of the long-run co-integration relationship, which encompass model is presented in the table below in a clear and structured manner.

Table 6: Long run Cointegration Results

Dependent variable, $lnCO_2t$: Regressor			
Model 1			
Variable	**Coefficient**	**Std. Error**	**T-ratio (p value)**
Yt	0.001	0.0005	2.350*(.065)
lnY2t	-2.018	0.598	-3.374**(.019)
lnUBt	1.397	0.262	5.330***(.003)
lnTRt	0.676	0.137	4.927***(.004)
lnENt	-4.725	0.658	-7.176***(.000)
lnFDt	0.356	0.0821	4.336***(.007)
lnCFt	-0.346	0.191	-1.805(.131)

***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 6 presents the comprehensive long-run results covering the period from 1971 to 2020, with CO_2 emissions as the dependent variable. A significant positive correlation is observed between CO_2 emissions and GDP per capita income at the 1% significance level, indicated by a coefficient of 0.597%. Specifically, a 1% increase in GDP per capita corresponds to a 0.597% rise in environmental degradation, which in turn leads to a decline in environmental quality. This illustrates the complex trade-off often associated with economic growth, particularly evident during the early stages of development when industrialization tends to drive up CO_2 emissions and ecological challenges.

As a result, the observed association supports the hypothesis that increasing economic activity, particularly in the industry, transportation, and energy consumption sectors, is associated with higher CO_2 emissions and subsequent environmental degradation. It is crucial for countries to accumulate enormous wealth and prioritize environmental legislation and cleaner technology. Yet, the positive link between GDP growth and environmental degradation persists in the both short and long-run estimation. As a result, the long-run model estimates show a positive coefficient for per capita income (Y_t) and a negative coefficient for the square of per capita income (lnY_t^2). The data validate the Environmental Kuznets Curve hypothesis, which states that environmental deterioration in Nigeria initially rises with per capita income and then drops after reaching a high.

The relationship between the urban population growth rate (referred to as lnUBt) and CO_2 emissions (referred to as $lnCO_2t$) reveals a significant finding within environmental research. The analysis indicates a coefficient value of 1.39%, which is statistically significant at the 1% level. This strong positive correlation suggests that as urban populations increase, CO_2 emissions also rise, raising essential concerns regarding environmental sustainability. Specifically, the data indicate that for each 1% increase in the urban population growth rate, CO_2 emissions rise by approximately 1.39%. This relationship highlights the substantial impact of urbanization on environmental health, demonstrating how the expansion of urban areas contributes to air quality degradation through increased emissions. In practical terms, this means that the rapid growth of urban populations is closely associated with a proportional increase in CO_2 emissions. Notably, a 1% rise in urban population can lead to a 1.397% increase in environmental deterioration, particularly concerning greenhouse gas emissions. These findings underscore the pressing need to address urban growth in the context of climate change and environmental policy, as effective management of urbanization can play a crucial role in mitigating its negative environmental impacts.

Hence, this highlights the link stuck between urbanization and heightened CO_2emissions and its environmental implications. This aligns with earlier research indicating that urbanization typically increases CO_2 emissions, especially in developing countries. Urban areas typically exhibit heightened economic activity, elevated energy consumption, and increased transportation demands, leading to higher emissions. Urban expansion often leads to increased carbon footprints due to heightened infrastructure, energy, and mobility demands unless substantial shifts towards sustainable practices or renewable energy sources are implemented (see Akorede & Afroz, 2020).

CO_2 emissions exhibit a 1% positive correlation with trade openness ($lnTR_t$), with a coefficient of 0.676. A 1% increase in trade openness causes a 0.676% decrease in environmental quality. This means that when countries increase their trade activities, they often harm the environment more. Factors such as increased industrial production, higher transportation emissions, and more resource use typically lead to this decline in environmental health. This indicates a prevalent concern regarding the connection between international trade and environmental damage. The primary concept is that increased openness to trade among nations typically results in heightened industrial production, transportation, and resource extraction, which may elevate CO_2 emissions and environmental degradation unless mitigated by sustainable policies.

Foreign direct investment (FDt), as measured by the natural logarithm of FDI (lnFDt), shows a positive and statistically significant correlation with CO2 emissions. This suggests that an increase in foreign direct investment is associated with a rise in CO2 emissions within the host country. This observation supports the argument that FDI can contribute to environmental degradation, particularly when it is directed toward carbon-intensive or high-cost sectors. Specifically, a 1% increase in foreign direct investment may result in a 0.356% decrease in environmental quality. The influx of foreign capital can exacerbate ecological degradation.

At the 1% level, the correlation between energy consumption ($lnEN_t$) and CO_2 emissions is statistically significant and detrimental, with a coefficient of -4.725%. This finding highlights the potential for change, as a 1% rise in energy consumption ($lnEN_t$) is associated with a 4.72% deterioration in environmental quality. It indicates that energy utilization negatively impacts the environment, particularly with CO_2 emissions and related ecological issues. This suggests that heightened energy usage is associated with increased environmental damage, but also presents an opportunity for improvement. Domestic capital flow, presumably reflecting domestic investment or savings, negatively correlates with CO_2 emissions; still, this association is statistically negligible. This indicates that fluctuations in domestic capital flows do not substantially or consistently impact CO_2 emissions in this scenario.

As estimated from the two long-run models, the study findings reveal that GDP per capita income (Y_t) has a positive coefficient, while squared per capita income (lnY_t^2) has a negative coefficient. These results not only support the Environmental Kuznets Curve concept but also have significant implications for environmental policy and economic development. Our study supports the EKC hypothesis, which shows an inverted U-shaped link between environmental degradation and per capita income in Nigeria. This finding increases interest and involvement in this area of research.

This finding aligns with previous studies on the EKC hypothesis in Nigeria, including those by Omisakin (2009), Alege & Ogundipe (2013), Egbetokun et al., (2020), Tenaw & Beyene (2021), Maduka et al., (2022), and Nketiah et al., (2024). The findings of Jalil & Mahmud (2009) for China are consistent with this outcome, Bölük & Mert (2015) for

Turkey, Mehmood & Tariq (2020) for South Asia, Bibi & Jamil (2021) for various global regions, Frodyma et al., (2022) for European countries, and Shahbaz (2022) for 11 countries. These studies collectively indicate that economic growth influences the environment, establishing a clear correlation between economic growth and ecological degradation in the early stages of growth. The findings contradict earlier studies suggesting the nonexistence of the EKC hypothesis, including those by Useno bong & Chukwu (2011), Sulaiman et al., (2013), Ogundipe et al., (2014), Minlah & Zhang (2021), and Onifade (2022).

Table 7: Results of the Short Run Cointegration Relationship

C	24.869	1.119	22.218***(.000)
D(LNCO$_2$(-1))	-0.543	0.052	-10.367***(.000)
D(LNCO$_2$(-2))	-0.629	0.046	-13.512***(.000)
D(LNCO$_2$(-3))	-0.378	0.037	-9.994***(.000)
D(Y)	0.0004	0.000	2.941**(.032)
D(Y(-1))	-0.0001	2.83E	-6.836***(.001)
D(Y(-2))	-4.71E	3.30E	-1.425(2.13)
D(LNY2)	-0.668	0.160	-4.154***(.008)
D(LNUB)	0.988	0.061	16.130***(.000)
D(LNUB(-1))	0.503	0.067	7.413***(.000)
D(LNUB(-2))	0.362	0.046	7.801***(.000)
D(LNUB(-3))	0.479	0.041	11.646***(.000)
D(LNTR)	0.131	0.011	11.893***(.000)
D(LNTR(-1))	-0.123	0.011	-10.486***(.000)
D(LNTR(-2))	-0.117	0.009	-11.833***(.000)
D(LNTR(-3))	-0.026	0.013	-1.941(.109)
D(LNEN)	-0.466	0.154	-3.027**(.029)
D(LNEN(-1))	1.835	0.144	12.739***(.000)
D(LNEN(-2))	1.327	0.140	9.484***(.000)
D(LNEN(-3))	-0.236	0.121	-1.939(.110)
D(LNFD)	0.002	0.004	0.5431(.610)
D(LNFD(-1))	-0.122	0.008	-15.103***(.000)
D(LNFD(-2))	-0.059	0.007	-7.854***(.000)
D(LNFD(-3))	-0.021	0.005	-4.357***(.007)
D(LNCF)	-0.110	0.012	-8.722***(.000)
D(LNCF(-1))	0.282	0.015	17.969***(.000)
D(LNCF(-2))	0.325	0.026	12.337***(.000)
D(LNCF(-3))	0.185	0.017	10.843***(.000)
CointEq(-1)*	-0.482	0.021	-22.214***(.000)

***, **, and * are significant at 1%, 5%, and 10% levels, respectively

EC = LNCO₂ - (0.0012*Y -2.0189*LNY2 + 1.3974*LNUB + 0.6761*LNTR - 4.7259*LNEN + 0.3561*LNFD -0.3464*LNCF) R2 = 0.994 DW Stat = 3.589 Schwarz criterion =-5.026 F- stat 75.826***(000)

The short-run results demonstrate a striking trend: carbon dioxide emissions ($lnCO_2$) as a dependent variable positively correlate with per capita income. This correlation, significant at the 5% level, is a clear indication of the impact of economic growth on the environment. The coefficient for per capita income (lnYt) is 0.0004%, further emphasizing the positive and significant results. This suggests that a rise in per capita income is associated with increased CO_2 emissions from the transportation sector. This illustrates the principle of the "environmental Kuznets curve," which asserts that economic expansion first leads to heightened pollution levels. Nevertheless, this relationship reverses at elevated income levels, forming a U-shaped curve. In this context, more incredible wealth correlates with elevated carbon emissions in the short term, primarily attributable to rising transportation demand and the adoption of more energy-intensive transportation technologies. These findings suggest that policies aimed at increasing income levels and promoting sustainable transportation alternatives could be effective in reducing emissions in Nigeria.

At the 1% significance level, the coefficient for per capita income squared ($lnYt^2$) is -0.67%, demonstrating a significant negative relationship. This indicates that income increases have a diminishing impact on emissions after reaching a specific threshold. As per capita income increases, the rate of growth in CO_2 emissions diminishes and ultimately declines. This suggests that once a specific income threshold is achieved, additional financial resources may facilitate the adoption of more sustainable transportation alternatives, including electric vehicles, improved public transit systems, or superior urban planning, thereby reducing emissions.

The error correction term (–0.48) meets the econometric criterion, being both negative and significant, indicating the functioning of the feedback mechanism. The error correction term is a crucial component of the model, as it measures the speed at which the dependent variable (CO_2 emissions from transport) adjusts to its long-run equilibrium level after a shock. In this case, the error correction term of -0.48 indicates that CO_2 emissions from transport exhibit an adjustment of approximately 48% within the initial period of less than one year when they deviate significantly from their equilibrium level. The complete convergence to the equilibrium level occurs in less than one year. In the event of an emissions shock, the rate at which equilibrium is attained is rapid and substantial, which is a significant finding of this study.

The diagnostic test results, a testament to the thoroughness of our research process, underscore the significance of our findings. They reveal the models' lack of serial correlation, functional form problems, misspecification, and heteroscedasticity. Table 8, a comprehensive summary, presents each model's R-squared, DW-statistic, Schwarz

Bayesian criterion, and F-statistics, demonstrating that the five models exhibit a satisfactory goodness of fit.

Table 8 Diagnostic Test

Test statistics	LM version	F-version
Model		
A: Serial correlation	CHSQ (1=) =2.058(0.151)	F(1,35)= 1.603(0.214)
B: Functional form	CHSQ (1=) =0.975(0.343)	F(1, 17)=0.949(0.343)
C: Normality	CHSQ (2=) =0.497=(0.816)	Not applicable
D: Heteroscedasticity	CHSQ (10=)8.303(0.599)	Prob. F(10,36)=0.772(0.654)

Note: Values in brackets represent p-values. LM = Lagrange Multiplier; A = LM test for residual serial correlation; B = Ramsey RESET test using squared fitted values; C = Test based on residual skewness and kurtosis; D = Test based on regressing squared residuals on squared fitted values; CHSQ = Chi-square statistic.

These findings not only validate our research but also highlight the importance of our study in understanding the relationship between economic expansion and environmental degradation.

Diagnostic tests for serial correlation, functional form, normality, and heteroscedasticity were conducted to verify the reliability of the estimates, as presented in Table 8. The results suggest that the null hypotheses for all tests remain accepted. All five models exhibit no serial correlation, heteroscedasticity, or normality issues. This confirms that these models are reliable and capable of producing precise results, instilling confidence in the accuracy of the results. The stability of the parameters was ultimately evaluated. Brown et al., developed the CUSUM and CUSUMSQ graphs. The statistics presented in this figure lie within the critical boundaries, indicating the stability of the coefficients.

FMOLS and DOLS Estimators for Robustness

The Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) methodologies were developed by Phillips and Hansen in 1990 and by Stock and Watson in 1993, respectively. Both methods produce asymptotically efficient coefficients, accounting for serial autocorrelation and endogeneity, and are exclusively used in the context of integrated order I(1) for all variables. However, DOLS is more adaptable than FMOLS, making it a more appealing option.

Ordinary Least Squares (OLS) can display bias when applied to cointegrated but nonstationary variables, while FMOLS does not suffer from this issue. In various studies, including one by Kao and Chiang (2000), it has been noted that DOLS often outperforms FMOLS. DOLS requires less computational intensity and is more effective at removing bias than FMOLS. Additionally, DOLS produces a t-statistic that more closely approximates the standard normal distribution compared to OLS or FMOLS. Importantly, DOLS estimators are entirely parametric and do not require pre-estimation or non-parametric corrections. According to Ali et al. (2017), one of the main advantages of DOLS is its ability to account for the heterogeneous order of integration among variables within the cointegration framework.

Table 9: The Estimated Results for the Impact of Economic Growth on CO_2 emissions Using Panel DOLS and FMOLS

Dependent variable=CO_{2t}: Regressors	**Dynamic OLS**		**Fully modified OLS**	
	Coefficient	**SE**	**Coefficient**	**SE**
Long-run coefficients				
GDP per capita (Y_t)	0.0004** (0.021)	0.0001	0.0004** (0.026)	0.0001
GDP per capita Square ($\ln Y_t^2(-1)$)	-0.3051*** (006)	0.1410	-0.6694** (0.009)	0.1103
% of Urban Pop growth ($\ln UB_t(-3)$)	0.9881*** (.000)	0.0530	0.9832*** (000)	0.0515
Trade openness (TR(-2))	0.1313*** (.000)	0.0076	0.1298*** (.000)	0.0078
Energy consumption ($\ln EN_t$)	-0.4668** (.047)	0.0963	-0.4589** (010)	0.0797
Foreign direct investment ($\ln FD_t(-1)$)	0.0471*** (.000)	0.0033	0.0470*** (001)	0.0042
Domestic Capital Flow $\ln CF_t$	-0.1105*** (.000)	0.0109	-0.1096*** (.000)	0.0137
Consant (C)	24.8698*** (000)	7.804	24.8540*** (000)	2.0776

Note. Parentheses are the t-statistics. DOLS = dynamic ordinary least square; FMOLS = fully modified ordinary least square; OLS = ordinary least square. ***, **, * Indicates significant at 1%, 5% & 10% level.

Subsequently, we utilized dynamic OLS and FMOLS to verify the robustness of the ARDL findings, with the estimated results presented in Table 9. Both DOLS and FMOLS indicate a negative correlation with per capita income square (Yt^2) and a significant positive correlation between carbon dioxide emissions from transportation ($\ln CO_{2t}$) and per capita income ($\ln Y_t$). The findings not only align but also strongly support the

Environmental Kuznets Curve hypothesis, which posits that environmental degradation increases with rising per capita income until it peaks, after which it declines (Grossman & Krueger, 1995; Shafik, 1994). The EKC hypothesis posits an inverted U-shaped correlation between environmental degradation and per capita income. The results align with the robustness outcomes of Model. This analysis confirms the long-run findings of the ARDL, indicating that these variables are significant predictors of CO_2 emissions. The long-run ARDL results indicate that the primary factors of economic growth, urban population expansion, trade openness, and foreign direct investment significantly influence environmental quality in Nigeria.

The analysis of fossil fuel consumption shows a dual impact: it has a positive effect on environmental degradation in the short term, but a negative effect in the long term. This finding highlights the changing landscape of Nigeria's energy sector as it transitions. Overall, the study emphasizes the urgent need for comprehensive, forward-looking policy frameworks that balance economic growth with ecological preservation. Sustainable development strategies should prioritize clean energy, efficient urban planning, and environmentally responsible investments to achieve long-term ecological stability in Nigeria.

Conclusion and Policy Recommendation

This research examines the connections stuck between economic growth, urbanization, trade openness, foreign direct investment (FDI), energy consumption, and carbon dioxide (CO_2) emissions in Nigeria from 1971 to 2020. The findings support the Environmental Kuznets Curve (EKC) hypothesis, demonstrating that CO_2 emissions initially increase with GDP per capita, with a 1% rise in GDP associated with a 0.597% increase in emissions, before subsequently declining after a certain income threshold is reached. Urbanization has a significant influence on emissions, as a 1% increase in the urban population is correlated with a 1.39% rise in emissions. Trade openness and foreign direct investment (FDI) increase emissions by 0.676% and 0.356%, respectively. Energy consumption significantly impacts environmental quality, with a 1% increase resulting in a 4.72% decrease, primarily due to the dependence on fossil fuels. Domestic capital flows exhibit minimal influence, suggesting that opportunities for sustainable investment remain unexploited. Both short- and long run findings suggest support for the Environmental Kuznets Curve (EKC), particularly within the transport sector, where initial income growth is associated with increased emissions, followed by a transition to cleaner technologies. Therefore, income growth alone is insufficient to achieve environmental benefits without accompanying policies. Essential policy recommendations include investment in renewable energy, sustainable planning for urbanization management, aligning trade and foreign direct investment with environmental objectives, implementing carbon pricing, and enhancing local capacity for green technology. In summary, Nigeria's economic growth has led to environmental challenges; however, the EKC framework suggests opportunities for improvement at higher income levels through proactive policy measures. This research enhances the comprehension of sustainable growth within developing economies.

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