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RE-EXAMINING THE KEY DRIVERS OF ENVIRONMENTAL DEGRADATION IN NIGERIA: A DYNAMIC ARDL APPROACH

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Abstract: This study aims to re-examine the key drivers of environmental degradation in Nigeria, focusing on the roles of financial development, foreign direct investment (FDI), and economic growth. It employs a dynamic Autoregressive Distributed Lag (ARDL) approach and the non-parametric Diks and Panchenko (2006) Granger causality test to analyse quarterly time series data from the first quarter (Q1) in 1970 to the fourth quarter (Q4) of 2022. The findings revealed a significant positive impact of financial development and FDI inflows on environmental degradation, both in the short and long run. The study validated the Environmental Kuznets Curve (EKC) hypothesis, demonstrating an inverted U-shaped relationship between economic growth and environmental degradation. The non-parametric causality test uncovered a non-linear bidirectional causal relationship between environmental degradation and financial development and a unidirectional causality running from FDI to environmental degradation. The study contributes to the existing literature by providing empirical evidence from Nigeria that supports the EKC hypothesis and by employing dynamic models and non-parametric tests to account for potential nonlinearities and dependencies. It offers insights into the complex interplay between economic factors, financial development, and environmental degradation, highlighting the need for a holistic approach to address environmental degradation while promoting sustainable economic development.

Keywords: Autoregressive Distributed Lag, Diks and Panchenko (2006) Granger causality, environmental degradation, Nigeria.

Introduction

Environmental degradation has emerged as a critical issue in contemporary discourse, with far-reaching implications for the planet's ecological balance and human well-being. Nigeria a country endowed with abundant natural resources has not escaped grave abnormal environmental degradation. This includes desertification, deforestation, soil erosion and air and water pollution (Muhammad *et al.,* 2023). These environmental challenges are substantially exacerbated by the country's population growth, declining urbanisation and industrialisation, among other factors. From the first quarter (Q1) of 1970, the Nigerian environment has been under heavy pressure from anthropogenic activities such as oil and gas exploration and mining, farming and rapid urbanisation (Adi *et al.,* 2023). The country's

oil-based economy has created environmental damage on a national scale, where its most significant pollutants are crude oil, and the rest are the products of oil spills and gas flarings (Nwankwoally & Ogagaruet, 2011).

Also, unhealthy agricultural practices which include deforestation to clear land for farmland expansion and over-exploitation of fertilisers and pesticides have led to soil degradation and contamination of the water bodies, where the runoff ends up, and the decline in biodiversity. (Musah *et al.,* 2022). Nevertheless, the biggest health challenge, among the environmental damage is the health status of the individuals, especially the elderly and people with weak immune systems. Breathing polluted air, drinking polluted water, and being exposed to polluted soil have been linked to respiratory diseases like asthma, and illnesses like cancer (Emmanuel *et al.,* 2023). The degradation of natural resources like forests, cultivated land, and water bodies also affects food security and the livelihoods of inhabitants as well, particularly rural folk who are dependent on these natural resources (Ismail *et al.,* 2024). Another serious problem is that of job imbalance, which is the economic cost of environmental illnesses. The accumulation of treatments, healthcare costs, and productivity decline (Aiyetan *et al.,* 2017) imposed by environmental pollution and resource depletion have had a profound adverse impact on the Nigerian economy.

Additionally, the decay of natural resources may hinder the country's long-term growth prospects. The need for a re-examination of the major causes of environmental degradation in Nigeria cannot be overemphasised, to devise appropriate strategies in mitigating its adverse effects. This research paper can contribute towards finding a tangible and prudent solution to the current environmental dilemma facing Nigeria. Through a rethinking of the main forces driving this phenomenon, this research paper delivers scientifically approved notions to the policymakers and other key stakeholders by suggesting which underlying environmental deterioration factors warrant special attention. This knowledge is an indispensable element for the creation and implementation of approaches and policies, which will be able to reduce the possible negative consequences of environmental damage and establish the framework for sustainable development. Moreover, this research report is expected to add to the overall discussion on environment conservation as well as serve as a reference for other countries confronting similar challenges.

While aptly identifying the critical causes of environmental degradation, the research can develop detailed and solution-oriented actions and policies directed towards the root of the problem, not just its symptoms (Ahmad *et al.,* 2018; Kamalu *et al.,* 2019). Although environmental degradation in Nigeria has been studied by numerous researchers, there is not a lot of information on the crucial drivers of this human activity-induced issue, which is being holistically examined from a nationwide process perspective with dynamism. So far, many of the research endeavours have examined the deterioration of the environment from limited aspects, which ignored the complex dynamics involved. For example, deforestation, oil spills, and common pollution in urban areas which are examples of such limited analysis. Furthermore, most of these studies have pursued employing static methods or cross-sectional designs which may not be able to reflect the complexity of environmental degradation issue and its drivers in the long term. The proposed study aims to address this research gap by adopting a dynamic Autoregressive Distributed Lag (ARDL) approach, which allows for the examination of both the short-run and long-run relationships between the key drivers of environmental degradation in Nigeria. By employing the dynamic ARDL approach, the study contributes to a more nuanced and comprehensive understanding of the complex interrelationships between various socio-economic, demographic, and policy factors that influence environmental degradation in Nigeria.

Literature Review

Environmental degradation in Nigeria has always been a significant issue, and this erosion is affected by various contributory factors. Studies have tried to establish the compound influence that finance has on the deterioration of the environment in Nigeria, yet the findings are uncertain at best. Iorember *et al.* (2020) fitted the data on financial growth, economic growth, and energy usage into an ARDL bounds testing approach to find out how those factors affected environmental degradation in Nigeria between 1980 and 2018. The empirical findings showed that overall, financial development exerted a very strong positive influence on environmental degradation. This simply implies that financial sector growth led to increased carbon emissions and a huge ecological footprint.

On the other hand, financial pollution and population size were the dependent factors, while financial development was the main parameter, using the ARDL approach from 1970 to 2016 by Ali *et al.* (2019). Of course, the research results presented that financial development was substantially negative over long periods with regard to environmental degradation. Indeed, the findings implied that thanks to a well-developed financial system, investment in green technologies and environmentally friendly practices would be easier. Also, worth mentioning are the effects of FDI on the deteriorating environmental conditions in Nigeria. Such effects have been also subject to the literature. Le *et al.* (2022) employed the ARDL bounds testing technique to study the interdependence of FDI, economic growth and environmental degradation in Nigeria between 1970 and 2019. The report concluded that FDI represented a huge positive contribution to the long-term issues of the environment, in that foreign investments in those companies which involved extractive industries and pollution were large factors in increasingly high levels of carbon emissions.

Moreover, Olayunbo and Adediran (2020), on the contrary, pondered the extent to which FDI affects environmental quality in Nigeria through the application of the ARDL Model using data from 1980 to 2018. The findings suggested that generally, FDI had a considerable negative influence on the environment as time went by, which ensured clean technology FDI and promoted environmentally sustainable practices as the way of reducing environmental degradation. From the researchers to the policymakers, the functionality of economic growth as it relates to environmental degradation in Nigeria is debatable with both supportive and contrary arguments. Rahman *et al.* (2020) made use of the ARDL bounds testing approach to look into the EKC hypothesis in Nigeria for the period from 1971 through to 2018 and applied the ARDL bounds testing approach. The outcome provided more proof of the validity of the EKC hypothesis: i.e., the idea that the more the economy booms, the more the environmental degradation worsens before a level of gross domestic product (GDP) is reached after which the environmental factors start to improve with the intensification of the economic growth.

On the contrary, Liu *et al.* (2023) conducted an analysis on sustainability in Nigeria using the ARDL approach, analysing the effect of economic growth on environmental issues, urbanisation as well as energy consumption for the period from 1970 to 2019. Nigeria's studies, which were conducted over the past few years, showed that economic growth, both short-term and long-term, were proven to have a direct effect on the environmental degradation in the country. Contrary to the Environmental Kuznets Curve Hypothesis, the economic growth here enabled the continuity of increasing environmental degradation in Nigeria. Igwe *et al.* (2023) underscore the detrimental role of unsustainable agricultural practices in contributing to environmental degradation and deforestation in Ebonyi State, Nigeria. Their findings, backed by statistical evidence, highlight the widespread use of agrochemicals and fertilisers by farmers, which intensifies agricultural activity and triggers environmental degradation. The study identifies soil erosion as

a major pathway through which pollutants enter the environment, with a significant correlation between conventional agricultural approaches and ecological deterioration.

Yusuf (2023) examines the Environmental Kuznets Curve (EKC) hypothesis and the dynamic impact of socioeconomic variables on ecological sustainability in Nigeria. Employing the Autoregressive Distributed Lag technique, the study supports the existence of the EKC hypothesis, indicating an inverted U-shaped relationship between economic growth and environmental degradation in both the long and short run. Notably, energy consumption and total imports exacerbate environmental deterioration, while total exports and financial development exhibit mixed effects, improving environmental quality overall but contributing to biodiversity loss in the short run. Aladejare (2023) broadens the scope by examining the nexus between human well-being and environmental degradation in 29 African countries. Utilising panel data techniques, the study finds that globalisation, life expectancy, and human capital development are environmentally enhancing, aligning with a synergy between the environment and human well-being. In contrast, income growth and urbanisation are identified as detrimental to the environment, supporting the trade-off hypothesis in African countries.

Olumba *et al*. (2024) delve into the enabling environment for delivering land degradation neutrality (LDN) in Nigeria, highlighting the perspectives of local stakeholders. Their findings revealed the presence of relevant institutions and policy instruments, but a lack of sufficient funding, weak institutional capacities, and operational challenges hindered effective policy implementation. Moreover, land tenure insecurity and gender-biased land administration systems pose additional obstacles to achieving LDN targets. Celik *et al.* (2024) investigate the environmental effects of material productivity, footprint, and intensity in G-7 economies, using carbon and greenhouse gas emissions as environmental indicators. Employing the mean group dynamic least squares estimation approach, the study validates the EKC hypothesis for the United States and Germany. However, material productivity and intensity aggravated environmental degradation in France, Italy, and Japan, highlighted the need for more effective approaches to reduce material intensification across economic sectors.

Prempeh (2024) examines the role of financial development, globalisation, renewable energy, economic growth, and industrialisation in reducing environmental degradation in the ECOWAS region. Utilising panel regression and quantile estimation techniques, the study confirms an N-shaped EKC for the region, with financial development and renewable energy usage associated with lower environmental degradation, while globalisation and industrialisation have a deleterious impact on environmental quality. In the empirical literature review, there are opinions and scientific conclusions on the different results associated with financial development, foreign direct investment, and economic growth in Nigeria and their impact on environmental pollution. The variability of these two factors means that more research is needed to have a more general understanding of the inconsistency between them and how they affect the country's environmental quality. The investigations in this research paper takes off from where earlier research has ended, and presents, an opportunity to enhance the knowledge base.

The research model being used is the ARDL-based dynamic approach. This captures the short-run and long-run interrelationships among the main drivers and environmental degradation, giving essential information about the dynamic nature of the problem. Furthermore, the inclusion of multiple drivers (financial development, FDI, and economic growth) in a single study allows for a more holistic examination of their combined impact on the environmental degradation in Nigeria. This approach can shed light on the interrelationships and potential trade-offs or complementarities among these factors, informing more effective and targeted policy interventions.

Methodology

Data

The paper employed the Dynamic ARDL procedure, as well as the causality, to establish the long-run relationship and causal linkage between economic growth, financial development, FDI and environmental degradation. Secondary time series data that includes quarterly periods from 1970 Q1 to 2022 Q4 provided the basis for the research used. The data was mainly from the Central Bank of Nigeria (CBN) Statistical Bulletin (2024) and World Development Indicators (2024).

Empirical Model

The first goal of this study focuses on examining the relationship between the long-term and short-term effects of financial development, foreign direct investment, and a particular country's gross domestic product on environmental deterioration. This paper also studies the non-linear directional causality of economic growth, financial development, foreign direct investment, and environmental degradation in the case of Nigeria. The study utilises five variables and sets carbon dioxide emissions as a function of economic growth, financial development, foreign direct investment, and the square of economic growth, as shown in the equation below:

$$Co2_t = f(FD_t, FDI_t, GDP_t, GDP_t^2) \quad (1)$$

The model is rewritten in equation (2) below:

$$lnCo2_t = \alpha_0 + \varphi_1 lnNFD_{t-1} + \varphi_2 lnFDI_{t-1} + \varphi_3 lnGDP_{t-1} + \varphi_4 lnGDP^2{}_{t-1} + \mu_t \quad (2)$$

Where, $lnCo2_t$ is the natural logarithms of carbon emission, $lnNFD_t$ is the natural logarithms of Financial Development, is the natural logarithms of Gross Domestic Product, $lnGDP^2{}_t$ is the natural logarithms of square of Gross Domestic Product, t is the time, α_0 is the constant, φ_1 to φ_4 are the slopes, and finally, μ_t is the error term.

Unit Root Test

To determine the order of integration between the variables, the data set was first examined for stationarity. This study initially applied traditional unit root assessments such as the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), Dickey-Fuller Generalized Least Squares (DF-GLS), and Kapetanios and Shin Unit Root (KSUR) tests. While many researchers have unveiled that the unit root testing techniques do not consider possible structural breaks in the data, this results in a misapprehension of the conditions of stationarity (Umar *et al.,* 2015; Rafindadi & Yusof, 2015; Rafindadi & Ozturk, 2015; 2016; 2017; Rafindadi, 2015; 2016; Rafindadi & Ilhan, 2017; Rafindadi *et al.,* 2018; Rafindadi & Mika'Ilu, 2019; Rafindadi & Usman, 2019; 2021). However, to deal with this problem, this unit root examination was adopted; the Lee-Strazicich (LS) and Clemente-Montanes-Reyes (CMR) can accommodate up to two structural breaks.

Cointegration Approach

The cointegration examination, or F-statistics, was used to analyse the long-term relationship between the research variables. The cointegration of the study variables is ascertained by the F-statistics value (Akram, *et al.,* 2022). In cases when the computed F-statistics value is higher than the upper bound critical value, cointegration between the research variables is present. There is no cointegration if the F-statistic is less than the lower bound critical value (Kamalu, *et al.,* 2022). When the calculated F-statistics number lies between the higher and lower critical levels, the result is inconclusive (Irfan, *et al.,* 2023). Based on current methodological techniques, the following two hypotheses were developed to assess the cointegration between the dependent and independent variables in both models (Usman *et al.,* 2023):

$$H_0 : \propto_1 = \propto_2 = \propto_3 = \propto_4 = \propto_5 = \propto_6 = 0 \quad (3)$$

$$H_1 : \propto_1 \neq \propto_2 \neq \propto_3 \neq \propto_4 \neq \propto_5 \neq \propto_6 \neq 0 \quad (4)$$

If the variables in this study were found to be cointegrated based on the two hypotheses stated previously, the following equation was utilised to analyse the short and long-term relationship between them:

$$\begin{aligned}\Delta lnCO2_t =& \propto_0 + \propto_1 lnCO2_{t-1} + \propto_2 lnFD_{t-1} + \propto_3 lnFDI_{t-1} + \propto_4 lnGDP_{t-1} \\ &+ \propto_5 lnGDPSQR_{t-1} + \propto_5 T_{1988Q3t} + \propto_6 T_{1999Q3t} + \sum_{i=1}^{p} \gamma_1 \Delta lnCO2_{t-1} \\ &+ \sum_{i=1}^{p} \gamma_2 \Delta lnFD_{t-1} + \sum_{i=1}^{p} \gamma_3 \Delta lnFDI_{t-1} + \sum_{i=1}^{p} \gamma_4 \Delta lnGDP_{t-1} \\ &+ \sum_{i=1}^{p} \gamma_5 \Delta lnGDPSQR_{t-1} + \sum_{i=1}^{p} \gamma_5 \Delta T_{1988Q3t-1} + \sum_{i=1}^{p} \gamma_6 \Delta T_{1999Q3t-1} \\ &+ \varepsilon_t \end{aligned} \quad (5)$$

In the preceding equation, the Schwarz Information Criterion (SIC) was utilised for optimal lag selection, with the change operators denoted by t-1. For large sample sizes, SIC has been found to provide more accurate lag order selections. The elements explored in the above equations include $\propto_1$ to $\propto_6$ and γ_1 to γ_6. If cointegration exists between the study variables based on the F-statistics, the short and long-run dynamic ARDL simulation models were analysed further (Atiku *et al.,* 2021; Jan *et al.,* 2023).

Dynamic ARDL Simulations

The following precedents were set by previous researchers, this study employed the Dynamic ARDL Simulations model, originally proposed by Jordan and Phillips (2018). The dynamic ARDL simulations model was developed to address a limitation of the conventional ARDL framework regarding the inability to examine short- and long-term relationships between variables (Atiku *et al.,* 2022; Rahman *et al.*, 2023). By introducing positive and negative shocks to the independent variables while holding other predictors constant, the dynamic ARDL approach can automatically inspect, simulate, and forecast trajectories over time. If the variables exhibit cointegration, the dynamic ARDL model can assess simulated responses. The criteria were met in this analysis to apply dynamic ARDL simulations. The parameters in the model were simulated 5,000 times using multivariate normal distributions, in line with recent applications (Jan *et al.,* 2023).

$$\begin{aligned}\Delta lnCO2_t =& \omega_0 lnCO2_{t-1} + \tau_1 lnFD_t + \omega_1 \Delta lnFD_{t-1} + \tau_2 lnFDI_t + \omega_2 \Delta lnFDI_{t-1} \\ &+ \tau_3 lnGDP_t + \omega_3 \Delta lnGDP_{t-1} + \tau_4 lnGDPSQR_t + \omega_4 \Delta lnGDPSQR_{t-1} \\ &+ \tau_5 T_{1988Q3t} + \omega_5 \Delta T_{1988Q3t-1} + \tau_6 T_{1999Q3t} + \omega_6 \Delta T_{1999Q3t-1} + \sigma ECT_{t-1} \\ &+ \varepsilon_t \end{aligned} \quad (6)$$

The above equation shows the dynamic ARDL simulations model, where rrepresents the long-run coefficients, denote the short-run coefficients, and ECT signifies the error correction terms. The ECT examines the adjustment speed from disequilibrium back towards an equilibrium eventually.

Granger Non-causality Test

This analysis utilises the nonparametric Diks and Panchenko (2005; 2006) Granger causality assessment to investigate potential non-linear causal linkages between economic expansion, financial sector development, foreign direct

investment inflows, the square of GDP growth, and environmental degradation across Nigeria. Unlike traditional linear Granger methods, this approach based on conditional independence testing can capture more complex dynamic causal relationships between time series (Ahmed & Sleem, 2023). The null hypothesis states that the variables are conditionally independent, implying an absence of predictive causality over time (Bouezmarni *et al.,* 2024). Recent research has applied this technique to examine interconnected economic, financial, and environmental factors motivated its selection for this study. Testing for non-linear lagged dependencies can provide unique causal insights not evident through linear modelling alone. The Diks-Panchenko approach has gained increasing recognition for enabling more flexible and sensitive detection of causal mechanisms tied to sustainability issues.

Ω_t on the $\emptyset_{t-1}, \ldots, \emptyset_{t-\ell_x}$, assumed the $\Omega_{t-1}, \ldots, \Omega_{t-\ell_x}$; Hence,

$$\mathrm{H}_0: \Omega_{t+1} \left| \left(\emptyset_t^{\ell_\emptyset}; \Omega_t^{\ell_\emptyset} \right) \sim \Omega_{t+1} \right| \Omega_t^{\ell_x}, \quad (7)$$

It must comply with its marginal:

$$\frac{f_{\emptyset,\Omega,\infty}(\emptyset,\Omega,\infty)}{f_\Omega(\Omega)} = \frac{f_{\emptyset,\Omega,\infty}(\emptyset,\Omega)}{f_\Omega(\Omega)} \cdot \frac{f_{\Omega,\infty}(\Omega,\infty)}{f_\Omega(\Omega)} \quad (8)$$

The vector for each in the provision of Diks and Panchenko additionally show that the null hypothesis indicates:

$$r \equiv Q\left[f_{\emptyset,\Omega,\infty}(\emptyset,\Omega,\infty) f_\Omega(\Omega) - f_{\emptyset,\Omega}(\emptyset,\Omega) f_{\Omega,\infty}(\Omega,\infty)\right] = 0 \quad (9)$$

$$T_n(\pi_n) = \frac{n-1}{n(n-2)} \sum_i \left(\hat{f}_{\emptyset,\Omega,\infty}(\emptyset_i,\Omega_i,\infty_i)\hat{f}_\Omega(\Omega_i) - \hat{f}_{\emptyset,\Omega}(\emptyset_i,\Omega_i)\hat{f}_{\Omega,\infty}(\Omega_i,\infty_i)\right) \quad (10)$$

Results and Discussion

The descriptive statistics of carbon dioxide (CO2) emissions, financial development (FD), foreign direct investment (FDI), gross domestic product (GDP), and its square (GDP2) are shown in Table 1. The central tendency measures display mean values during the examined period, revealing an average of 11.106 CO2 emissions, 20.777 FD, 25.198 FDI, and 636.183 GDP. Standard deviation values indicate a higher degree of variance, which confirms the volatility typically

Table 1: Descriptive statistics

	lnCO2$_t$	**lnFD$_t$**	**lnFDI$_t$**	**lnGDP$_t$**	**lnGDP SQR$_t$**
Mean	11.106	-0.497	20.777	25.198	636.183
Std. Dev.	0.459	0.864	1.209	1.102	55.689
Skewness	-0.217	0.364	0.320	0.100	0.169
Kurtosis	2.154	1.987	1.719	2.095	2.047
lnCO2$_t$	**1.000**				
lnFD$_t$	0.542*	**1.000**			
	(0.000)				
lnFDI$_t$	0.606*	0.461*	**1.000**		
	(0.000)	(0.000)			
lnGDP$_t$	0.559*	0.661*	0.405*	**1.000**	
	(0.000)	(0.000)	(0.000)		
lnGDP SQR$_t$	0.660	0.563*	0.808*	0.589*	**1.000**
	(0.000)	(0.000)	(0.000)	(0.000)	

observed in macroeconomic time series (Javed *et al.,* 2023). The distributional shapes are shown by the skewness and kurtosis coefficients; non-zero skewness and kurtosis values deviate from a normal distribution by matching with the features of the underlying economic data. There are statistically significant, correlations between the indicators, as seen by the correlation matrix. Correlations less than 0.85; however, point to the lack of detrimental multicollinearity that jeopardises regression analysis (Ahmad *et al.,* 2015a; 2015b). GDP and CO_2 emissions had the strongest correlation (0.808), which is consistent with emissions generally following economic activity. Additionally, there were strong connections between financial development and FDI (0.661) and GDP (0.608), suggesting that finance grows in tandem with increased investment flows and economic advancement. The wide correlations indicate connections between the financial system, foreign direct investment, growth in the country's income, and environmental effects.

Table 2 presents traditional unit root test findings from DF-GLS, ADF, PP, and KSUR approaches, which does not account for structural breaks (Ahmad *et al.,* 2015c). The results signified all variables were stationary at first differences, I (1). However, ignoring breaks can yield ambiguous outcomes (Igwe *et al.,* 2023). Therefore, this study implemented the Lee-Strazicich (LS) and Clemente-Montanes-Reyes (CMR) examinations allowing two unknown structural breaks to mitigate issues. Table 3

Table 2: Traditional unit root tests

VARIABLES	DF-GLS	ADF	PP	KSUR
$\ln CO2_t$	-1.739	-2.299	-2.808	-2.156
$\ln FD_t$	-2.321	-3.346	-2.619	-2.350
$\ln FDI_t$	-2.742	-2.726	-2.279	-2.359
$\ln GDP_t$	-2.472	-2.528	-1.653	-2.604
$\Delta lnCO2_t$	-5.689*	-5.431*	-7.449*	-4.397*
$\Delta lnFD_t$	-4.646*	-4.893*	-7.846*	-4.839*
$\Delta lnFDI_t$	-5.130*	-6.115*	-8.886*	-5.232*
$\Delta lnGDP_t$	-4.125*	-4.533*	-6.816*	-5.470*

Table 3: Modern unit root tests

VARIABLES	LS		CMR	
	Intercept and Trend	Break-year	Intercept and Trend	Break-year
$\ln CO2_t$	-2.957	1988Q1 and 2000Q3	-2.067	1989Q4 and 2001Q1
$\ln FD_t$	-2.431	1980Q4 and 1981Q4	1.382	1993Q1 and 2007Q4
$\ln FDI_t$	-2.784	1998Q4 and 1999Q4	-2.875	1987Q3 and 2003Q3
$\ln GDP_t$	-2.513	1985Q4 and 2003Q4	-2.197	1981Q4 and 2009Q1
$\Delta lnCO2_t$	-6.084*	-1989Q3 and 1997Q4	-5.489*	1988Q3 and 1999Q3
$\Delta lnFD_t$	-5.725*	1978Q3 and 2007Q3	-8.861*	1980Q3 and 2006Q3
$\Delta lnFDI_t$	-7.731*	1993Q3 and 1998Q4	11.026*	1988Q3 and 1994Q3
$\Delta lnGDP_t$	-3.717**	1974Q4 and 1982Q3	-4.553**	1980Q3 and 1992Q3

reports the LS and CMR unit root test results. In the presence of two breaks, the variables were non-stationary at levels for Nigeria but became stationary at first differences, corroborating I (1) integration (Irfan *et al.,* 2023). Accounting for breaks confirmed all study variables reached stationarity after differencing, with series integrated of order one.

The dynamic ARDL framework assesses both short-term and long-term relationships, necessitating confirmation of cointegration (Pesaran *et al.,* 2001). They developed the ARDL bounds testing approach specifically for verifying cointegration. Table 4 displays bound test results for environmental degradation. The computed F-statistics fell outside the 99% upper bound critical value, indicating cointegration between the dependent and independent variables. Jordan and Philips (2018) originally proposed the dynamic ARDL model to examine the simultaneous impacts of chosen indicators in a multivariate setting, overcoming limitations of estimating long-run equilibriums separately from short-run dynamics.

The study examined the relationship between financial development (FD), foreign direct investment (FDI), GDP, and environmental degradation (measured by carbon dioxide emissions, or CO2) in Nigeria using a dynamic Autoregressive Distributed Lag (ARDL) model. To account for any cointegration among the variables, the ARDL technique enables the assessment of both short- and long-term connections between them (Pesaran *et al.,* 2001). With a significant error correction term (ECT) of -0.369, the data shown in Table 5 revealed that about 37% of the disequilibrium in environmental deterioration is rectified yearly. The long-run equilibrium relationship is confirmed to be stable by the ECT value, which falls between 0 and -1. When the individual variables are examined, the results show that financial development (FD) significantly improves environmental deterioration (CO2) over the long and short terms (coefficient = 0.134 and 0.265, respectively).

This suggests that a 1% rise in financial development causes environmental deterioration to increase by 13.4% over the long-term and by 26.5% over the short-term. These findings are consistent with other research (Iorember *et al.,* 2020), which indicates that the growth of the financial sector may exacerbate environmental deterioration by making credit more accessible, raising output, and boosting the demand for products and services that produce a lot of pollution. Nigeria's current efforts to promote financial inclusion and poverty reduction through loan extension to the general public might be ascribed to the positive relationship between financial development and environmental deterioration in the country. Even if the goal of these programmes is to improve economic well-being, higher levels of production and consumption may unintentionally result in increased emissions and pollution (Rahman *et al.,* 2020; Liu *et al.,* 2023).

The findings for FDI showed a favourable and noteworthy impact on CO2 emissions over the long- and short-terms. In particular, a 10% increase in FDI would cause environmental deterioration to rise by 17.2% over the long-term

Table 4: Cointegration test result

Cointegration Bounds Testing ($k = 7$)		
Estimated Models	*F*-statistics	
$lnCO2_t = f(lnFD_t, lnFDI_t, lnGDP_t, lnGDP\ SQR_t, T_{1988Q3}, T_{1999Q3})$	11.640*	
Level of significant	*I*(0)	*I*(1)
1% level	3.790	5.411
5% level	2.764	4.123
10% level	2.327	3.541

and by 8.9% over the short-term. According to these results, which are consistent with earlier studies (Le *et al.,* 2022), there is a chance that rising FDI inflows into Nigeria may worsen environmental deterioration. There are two main reasons why FDI and environmental deterioration have a beneficial association. First off, when compared to local businesses, international organisations frequently have better resource endowments, managerial skills, and environmental competencies. Consequently, they can embrace more environmentally friendly industrial technology and sophisticated environmental management techniques, which could enhance the environmental circumstances of the receiving nation (Chike *et al.,* 2023). Second, multinational corporations may have a "demonstration effect," which encourages smaller businesses to copy their environmental policies and so indirectly improve the condition of the environment.

The Environmental Kuznets Curve (EKC) theory, which postulates an inverse U-shaped relationship between economic growth and environmental degradation, must be carefully considered when including economic growth (EG) in environmental degradation models. The research incorporated both the linear and squared elements of EG in the model to take into consideration this possible non-linearity. The findings displayed in Table 5 demonstrated a positive correlation in the short (coefficient = 0.145) and long (coefficient = 0.165) terms between EG and environmental degradation. These results imply that in Nigeria environmental quality declines with rising economic activity levels, possibly as a result of more energy use and financial resource accessibility. Nonetheless, the inverted U-shaped relationship predicted by the EKC theory is supported by the negative and significant coefficients of the squared EG term (GDP SQR) in both the short and long runs.

The association between environmental deterioration (measured by CO2 emissions) and two dummy variables, T1988Q3 and T1999Q3, which stand for distinct periods, was also investigated in this study. The outcomes showed that T1988Q3 and T1999Q3 had the opposite effects on environmental deterioration. The coefficient values for T1988Q3 and T1999Q3 over the long term were -0.660 and -0.119, respectively, indicating a detrimental effect on CO2 emissions. But in the short-term, the impact decreased, with coefficients of -0.325 and -0.058, respectively. With an R-squared value of 0.54 (54%), the CO2 model had a comparatively high overall explanatory power, suggesting that the independent variables together explained a significant amount of the variation in environmental degradation. To assess the dynamic ARDL model's validity and robustness, model diagnostics are essential. The Breusch-Godfrey Lagrange Multiplier (LM) test, normalcy, heteroscedasticity, and serial correlation were all tested as diagnostic procedures in this study. The tests' chi-square values indicated that there was no evidence of heteroscedasticity or serial correlation, proving that the series were normally distributed and that the model was appropriately described.

Consequently, the dependability of the model was supported by the diagnostic test results, which did not reject the null hypothesis. The study used simulation graphs based on the dynamic ARDL model to represent the counterfactual effects of each variable on environmental degradation. These diagrams show the 70%, 90%, and 95% confidence intervals as coloured lines, and light and dark blue lines with a centre dot for the mean. Figures 1 through 6 shows how financial development (FD), foreign direct investment (FDI), GDP, squared GDP (GDP SQR), T1988Q3, and T1999Q3 was affected by 10% positive and negative shocks, respectively. In Figure 1, during the tenth simulation period, a ± 10% change in FD led to disequilibrium in CO2 emissions in both directions; however, the influence turned positive in the following decades. Figures 5 and 6 display the impulse response graphs for T1988Q3 and T1999Q3 on CO2 emissions. Positive shocks elicited a positive impulse

Table 5: Dynamic autoregressive distributed lag estimates results

Dependent Variable: LNCO2$_{it}$			
Variables	Coefficients	Stand. Error	P-value
$lnFD_t$	0.134** (2.270)	0.059	0.024
$\Delta \ln FD_t$	0.265** (2.820)	0.094	0.005
$lnFDI_t$	0.172* (3.881)	0.044	0.000
$\Delta \ln FDI_t$	0.089** (2.05)	0.043	0.042
$lnGDP_t$	0.163* (4.890)	0.033	0.000
$\Delta \ln GDP_t$	0.145** (2.850)	0.051	0.005
$lnGDP\ SQR_t$	-0.633* (-5.321)	0.119	0.000
$\Delta \ln GDP\ SQR_t$	-0.545* (-3.879)	0.141	0.000
$T_{1988Q3t}$	-0.660* (-4.876)	0.135	0.000
$\Delta T_{1988Q3t-1}$	-0.325** (-2.630)	0.124	0.009
$T_{1999Q3t}$	-0.119** (-2.030)	0.059	0.044
$\Delta T_{1999Q3t-1}$	-0.054** (-2.150)	0.025	0.033
ECT_{t-1}	-0.369* (-6.910)	0.053	0.000
R^2	0.540		
Adj-R^2	0.473		
Simulation	5000		
γ_{ser}	1.698 (0.147)		
γ_{Hetr}	0.956 (0.501)		
γ_{Nor}	1.742 (0.417)		

response, but negative shocks caused a negative shift in CO2 emissions. Both responses showed an initial rise in the opposite direction in the 10th session. Moreover, a 10% shock to T1988Q3 and T1999Q3 later on proved to have a harmful impact.

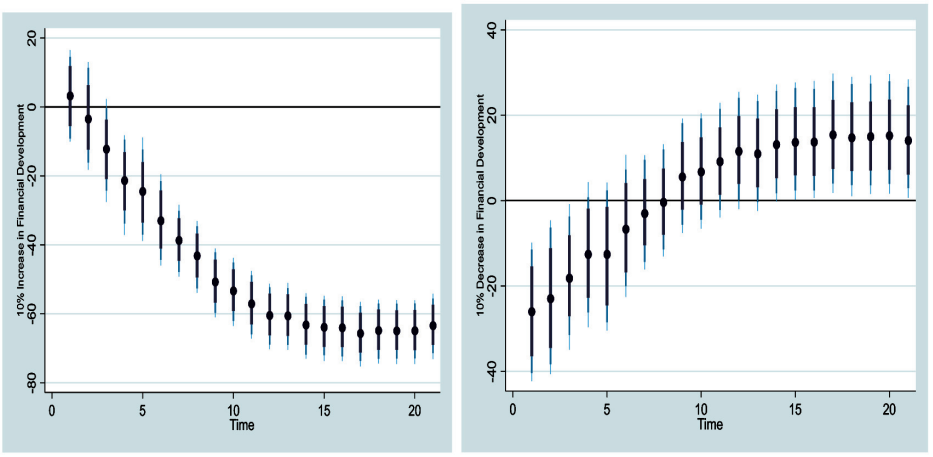

Figure 1: Financial development and CO_2

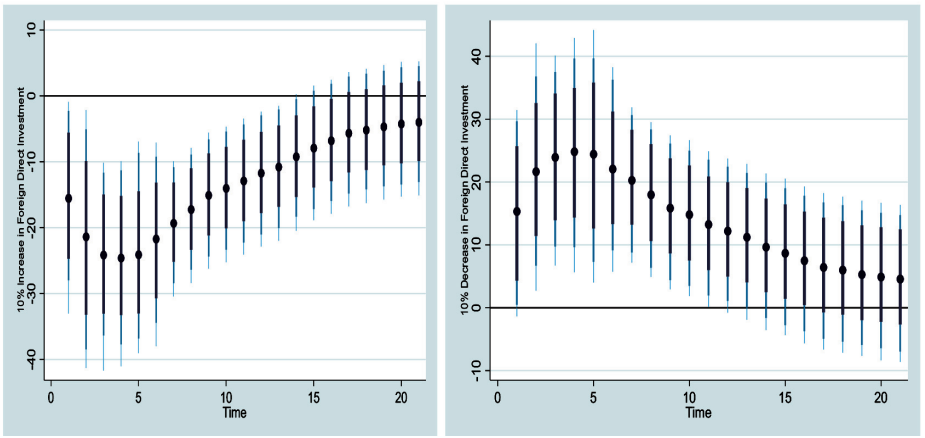

Figure 2: Foreign direct investment and CO_2

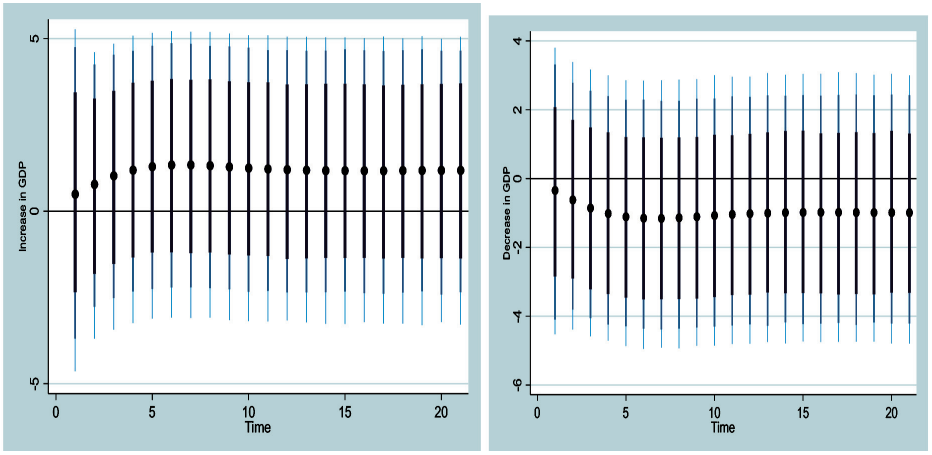

Figure 3: GDP and CO_2

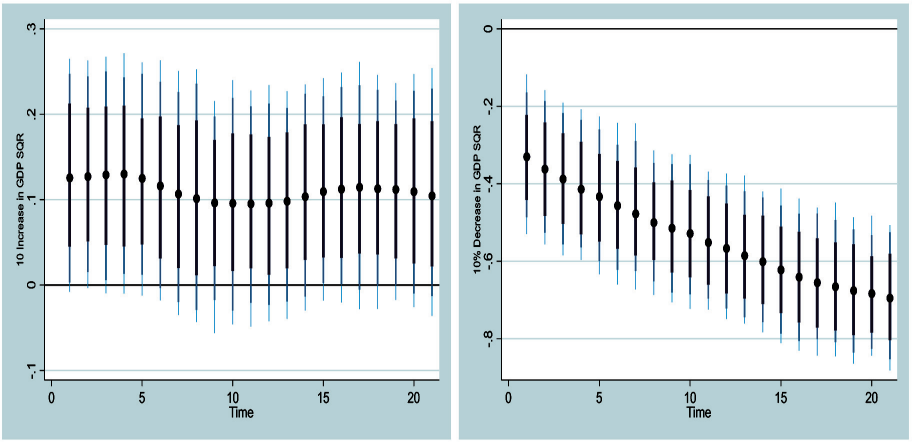

Figure 4: GDP SQR and CO_2

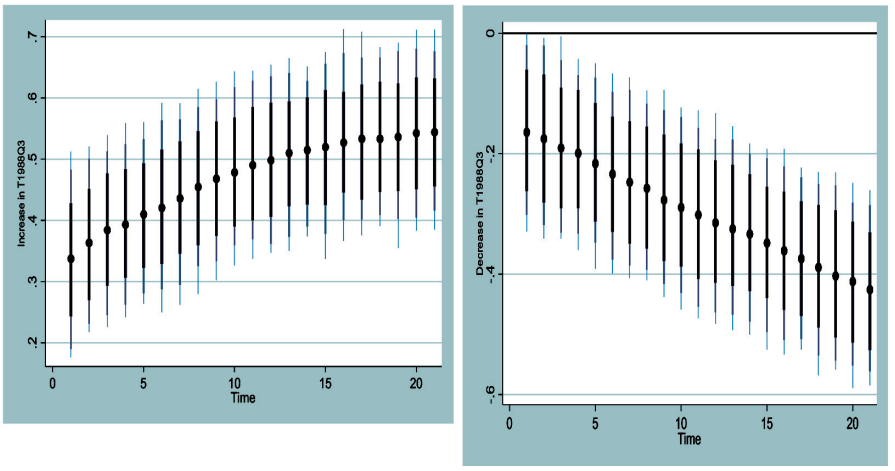

Figure 5: T_{1988Q3} and CO_2

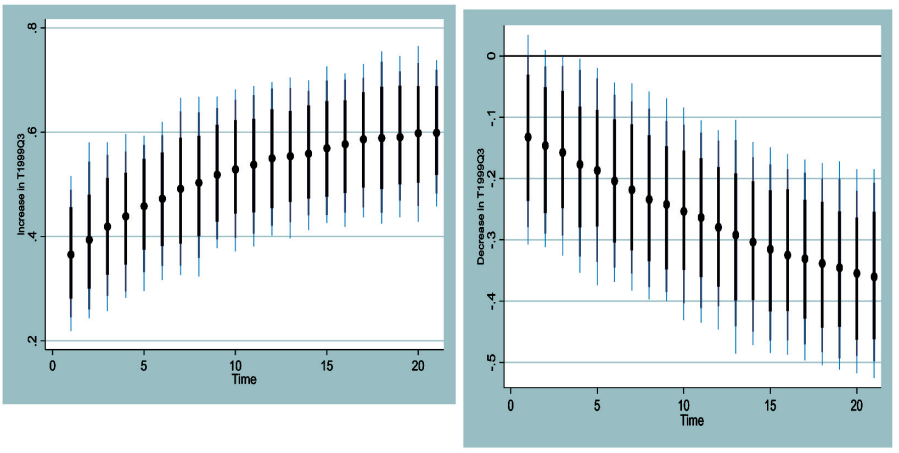

Figure 6: T_{1999Q3} and CO_2

The Diks and Panchenko (2006) non-parametric causality test was utilised in the study to investigate the causal linkages between the independent variables in the model and environmental deterioration. This method works well for identifying dependencies and other possible nonlinearities in the data. The tests were carried out with the bandwidth (ε-value) fixed at 0.5 for the duration of the sample period, as indicated in Table 6, and the lag lengths (ℓx and ℓy) were chosen following the Akaike Information Criterion. The findings showed several intriguing causal connections. First, a strong non-linear bidirectional causal link at both the 1% and 5% levels was discovered between financial development and environmental degradation. This implies that changes in environmental quality can have an impact on the development of the financial sector and that financial development also affects environmental deterioration (Musah *et al.,* 2022). Second, at the 1% significance level, the data supported a unidirectional causal relationship between environmental degradation and foreign direct investment (FDI). In line with earlier research, this suggests that FDI inflows cause environmental damage in Nigeria (Le *et al.,* 2022). Significantly, the findings also demonstrated a two-way causal relationship between environmental deterioration and GDP and its squared term (GDP SQR). This result confirms the existence of the Environmental Kuznets Curve (EKC) theory, which postulates that environmental deterioration and economic growth have an inverse U-shaped relationship (Rahman *et al.,* 2020; Liu *et al.,* 2023).

Managerial, Theoretical, Social, and Practical Implications of the Study

The research provides significant insights into the matter. The study emphasises the fact that to prevent possible future problems environmentally and with financial sector development and FDI inflows, policymakers and business players must act strategically and cautiously. Additionally, this study can prove that economic growth headwinds can intensify environmental degradation if it is not planned and executed sustainably. Managing and decision-making bodies should therefore engage in, energy-saving practices, responsible use of natural resources and make use of green technologies. Therefore, this can help to mitigate the negative environmental effects that arise due to expanded economic activities and industrial production. The demonstration effect of multinational corporations on corporate social responsibility (CSR) and sustainability policies of local firms can shed light on the importance of taking these policies into account when operating these organisations at the local

Table 6: Diks and Panchenko causality test

lnCO2 – /→ lnFD	**lnFD – /→ lnCO2**	**Direction**
2.507* (0.006)	2.229** (0.013)	Bidirectional
LnCO2 – /→ lnFDI	lnFDI – /→ lnCO2	
0.418 (0.337)	3.643* (0.000)	Unidirectional
LnCO2 – /→ lnGDP	lnGDP – /→ lnCO2	
2.232** (0.013)	1.740 (0.041)	Bidirectional
LnCO2 – /→ lnGDP SQR	LnGDP SQR– /→ lnCO2	
2.395* (0.008)	1.707** (0.044)	Bidirectional

or domestic level for the firms to be able to impact the operations of the local counterparts to employ the same principles.

The research owes its general view to the actual evidence from Nigeria of the Environmental Kuznets Curve (EKC) hypothesis by which economic development is an inverse U-shaped relationship that is linked to environmental degradation. The employment of the Dynamic ARDL model, as well as a non-parametric causality test, instead provides this method a contribution to mathematics by addressing the potential linear inequalities and domains ruled by dependency in the data that are usually ignored by the traditional linear methods. The results illustrate the multifaceted interaction between monetary progress, FDI, and economic growth, as well as ecological degradation, showing the need for an all-embracing and integrated way of relationship modelling and understanding of these bonds. The outcomes of the research are of great importance to society. It has a great bearing on public health, which is a universal right, clean water and air as well as the quality of the people's life. By highlighting the underlying causes of pollution and degradation, the research can be useful in determining what can be done to arrest these negative effects and champion environmental restoration initiatives that ensure the lifestyle of the present generation remains viable even in the future.

The bidirectional causality between environmental degradation and financial development highlights the potential for environmental quality to influence financial sector stability and performance, which can have broader socio-economic consequences. The study provides practical insights for policymakers and regulatory bodies in Nigeria, emphasising the need to develop and implement comprehensive environmental policies that address the potential negative impacts of the financial sector's development, FDI inflows, and economic growth. The results underscore the importance of promoting sustainable investment practices, encouraging the adoption of clean technologies, and implementing effective environmental regulations to ensure a balance between economic development and environmental protection. The research findings can inform the design and implementation of targeted interventions, such as incentives for eco-friendly practices, awareness campaigns, and capacity-building initiatives, to mitigate environmental degradation while fostering economic growth and development.

In addition, a key implication is the need to revisit and re-evaluate policies related to financial development and FDI inflows. While these factors contribute to economic growth, the study reveals their potential detrimental impact on the environment, at least in the short and long run. Therefore, policymakers must strike a delicate balance between promoting financial development, attracting FDI, and implementing stringent environmental regulations and incentives to encourage sustainable practices. The validation of the Environmental Kuznets Curve (EKC) hypothesis in the Nigerian context suggests that economic growth, up to a certain point, may exacerbate environmental degradation. However, beyond that point, further economic growth could potentially lead to improved environmental quality. This finding underscores the importance of pursuing economic policies that prioritise sustainable and inclusive growth, rather than solely focusing on short-term economic gains at the expense of the environment.

Moreover, the study's findings call for greater collaboration and coordination between various stakeholders, including the government, private sector, social welfare organisations, and local communities. Addressing environmental challenges requires a concerted effort and a shared responsibility among all stakeholders to implement effective policies, promote eco-friendly practices, and raise public awareness about the importance of environmental conservation. Furthermore, the study's findings have implications on Nigeria's commitments to international agreements and global initiatives aimed at addressing environmental challenges,

such as the Paris Agreement on climate change and the United Nations Sustainable Development Goals (SDGs). Nigeria must align its national policies and strategies with these global efforts, fostering international cooperation and leveraging available resources and technical expertise to achieve the SDGs and meet its environmental commitments.

Finally, the study's findings highlight the need for a delicate balance between promoting economic growth, financial development, and foreign direct investment while ensuring environmental sustainability. Policymakers must prioritise a multipronged approach to address these interconnected factors. Firstly, reforms within the financial sector are crucial. Regulations and incentives should be implemented to encourage sustainable lending practices and green finance initiatives. This can help mitigate the negative environmental impact associated with financial development. Additionally, strengthening environmental regulations and screening processes for FDI, particularly in sectors with high environmental footprints, is paramount. Incentivising FDI in eco-friendly industries and technologies can contribute to sustainable economic growth. Secondly, economic policies should prioritise sustainable and inclusive growth, focusing on sectors with low environmental impact promoting eco-friendly technologies and practices. Introducing environmental taxes on polluting activities and industries, while providing subsidies and incentives for businesses that adopt sustainable practices and invest in renewable energy sources, can further support this transition. Thirdly, fostering collaboration between the government, private sector, and social welfare organisations is vital. Public-private partnerships can leverage expertise and resources from all stakeholders to develop and implement sustainable development strategies effectively. Finally, robust monitoring and enforcement mechanisms, with appropriate penalties for non-compliance, are essential to ensure adherence to environmental regulations and sustainable development goals.

Limitations and Recommendations for Future Studies

The study relied on secondary time series data, which may be subject to measurement errors, inconsistencies, or omissions. Additionally, the availability of comprehensive and reliable environmental data, particularly for developing countries like Nigeria, can be a challenge, potentially limiting the scope and accuracy of the analysis. Proxy Variables: The study used carbon dioxide (CO_2) emissions as a proxy for environmental degradation. While CO_2 emissions are a critical environmental indicator, they may not fully capture other forms of degradation, such as deforestation, biodiversity loss, or water pollution. Future studies could explore the use of composite environmental indices or consider additional indicators to provide a more comprehensive assessment. Omitted Variable Bias: Although the study incorporated several key variables, such as financial development, foreign direct investment, and economic growth, there may be other relevant factors that could influence environmental degradation but were not included in the model. Omitting relevant variables can lead to biased estimates and potentially misleading conclusions.

While the dynamic ARDL model and non-parametric causality tests employed in the study have advantages in capturing non-linearities and dependencies, they may still be subject to certain assumptions and limitations. Alternative methodological approaches, such as panel data analysis or structural equation modelling, could be explored to validate and extend the findings. Expand the scope of analysis: Future research could consider a multi-country or regional analysis to examine the drivers of environmental degradation across different economic and geographical contexts. This would provide valuable insights into the generalisability of the findings and facilitate cross-country comparisons and policy recommendations. Incorporate additional variables: Researchers could explore the inclusion of other potential drivers of environmental degradation such as

energy consumption patterns, trade openness, technological innovation, institutional quality, and environmental regulations.

Considering a broader set of variables could provide a more comprehensive understanding of the complex dynamics influencing environmental degradation. Explore Nonlinearities and Threshold Effects: While the study accounted for potential non-linearities through the dynamic ARDL model and non-parametric causality tests, future research could delve deeper into the existence of threshold effects or regime-switching behaviours. This would shed light on potential tipping points or critical levels of economic growth, financial development, or FDI inflows that may significantly impact environmental degradation. Use of Alternative Methodologies: Future studies could employ alternative methodological approaches, such as panel data analysis, structural equation modelling, or dynamic stochastic general equilibrium (DSGE) models, to provide additional insights and robustness checks for the findings. These methodologies may offer complementary perspectives and address the potential limitations of the current study. Investigate Policy Interventions: Building upon the findings of this study, future research could explore the effectiveness of various policy interventions, such as environmental regulations, economic incentives, and technological innovations, in mitigating environmental degradation. Such analyses could inform policymakers and stakeholders to develop targeted and effective strategies to promote sustainable development while addressing environmental concerns.

Conclusions

The study employed a dynamic ARDL approach to investigate the long-term relationship and causal dynamics between economic growth, financial development, foreign direct investment (FDI), and environmental degradation in Nigeria. By utilising quarterly data spanning from the first quarter of 1970 to the fourth quarter of 2022, the research paper research was able to provide valuable insights into the complex interplay between economic growth, financial development, FDI, and environmental degradation. The findings revealed a significant positive impact of financial development on environmental degradation, both in the short and long run. This relationship can be attributed to the country's efforts to promote financial inclusion and alleviate poverty increased access to credit financing, leading to higher production and consumption levels, which inadvertently contributed to higher emissions and pollution levels. The study also highlighted a positive and significant effect of FDI inflows on environmental degradation, suggesting that increased foreign investment, particularly in extractive and pollution-intensive sectors, could exacerbate environmental issues in Nigeria.

Notably, the research validated the presence of the Environmental Kuznets Curve (EKC) hypothesis, demonstrating an inverted U-shaped relationship between economic growth and environmental degradation. While economic growth initially contributed to increased environmental degradation, and the significant negative coefficients of the squared economic growth in both the short and long run which was supported the EKC hypothesis, indicating that beyond a certain income threshold, further economic growth could lead to improvements in environmental quality. The non-parametric causality test employed in the study revealed several interesting causal relationships. A non-linear bidirectional causal relationship was found between environmental degradation and financial development, suggesting that changes in environmental quality can also influence the development of the financial sector. Additionally, the results confirmed a unidirectional causality running from FDI to environmental degradation, implying that FDI inflows have a causal impact on environmental degradation in Nigeria.

The study's findings have significant implications for policymakers, business leaders, and stakeholders in Nigeria. They highlight the need for a comprehensive and integrated

approach to address the drivers of environmental degradation while promoting sustainable economic development. Effective policies and strategies should prioritise the adoption of clean technologies, responsible resource utilisation, and the implementation of strong environmental regulations and corporate social responsibility practices. Furthermore, the research contributes to the theoretical literature by providing empirical evidence from Nigeria that supports the EKC hypothesis and by employing a methodological approach that accounts for potential nonlinearities and dependencies in the data. The study also underscores the importance of considering the complex interplay between economic factors, financial development, and environmental degradation in developing effective interventions and policy measures. While the study offers valuable insights, it is essential to acknowledge its limitations, such as data availability and quality, the use of proxy variables, potential omitted variable bias, and methodological constraints. Future research should address these limitations by expanding the scope of analysis, incorporating additional variables, exploring non-linearities and threshold effects, utilising alternative methodologies, and investigating the effectiveness of policy interventions in mitigating environmental degradation.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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