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DISTRIBUTIONAL INFLUENCE OF FINANCIAL DEVELOPMENT AND ECONOMIC GROWTH ON ENVIRONMENTAL SUSTAINABILITY IN NIGERIA: EVIDENCE FROM QUANTILE ARDL MODEL

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ABSTRACT: *This study investigates the distributional influence of financial development and economic growth on environmental sustainability in Nigeria. The study utlilized the novel quantile-based autoregressive distributed lag (QARDL) model. The findings reveal several critical insights: First, financial development significantly deteriorates environmental quality in both the short and long term, as evidenced by its positive impact on CO_2 emissions and ecological footprints across most quantiles—particularly at middle and upper quantiles where the effect intensifies. This confirms the distributional nature of financial development's environmental impact, indicating that economic expansion through financial deepening has been accompanied by higher environmental costs. Second, the findings on economic growth support the Environmental Kuznets Curve (EKC) hypothesis, showing that environmental degradation initially rises with growth but eventually declines at higher levels of income. This transition point, however, appears to occur only at upper quantiles, suggesting that Nigeria is still in the earlier stages of the EKC trajectory Third, the findings support the presence of asymmetry in the growth-finance-environmental quality relationship and underscore the distributional nature of the relationship across different environmental states. The study recommends the introduction of environmental risk assessments and sustainability criteria in financial sector lending and investment decisions and incentivise green financing products such as renewable energy loans, sustainable infrastructure bonds, etc. Also, government should channel economic growth toward sectors with lower carbon intensity through targeted tax incentives and subsidies.*

KEYWORDS: Financial development, economic growth, environmental sustainability, distributional influence, CO2, ecological footprint, quantile ARDL.

JEL Classification: C22, E01, E44, O13, O44.

INTRODUCTION

The relationship between financial development, economic growth and environmental sustainability is still an ongoing debate among academicians, researchers and policy makers. This is due to the fact that the major goal of both the developed and developing countries is the attainment of economic growth and sustainable development. Along the part of achieving this goal are some hindrances; while environmental degradation related cases form the most common contentious menace to reaching the desired sustainable development level, there is a complicating association between economic growth and environmental degradation (Khan et al 2020; Odhiambo, 2020; Rafindadi, 2016; Ochada,2020).

Environmental degradation has emerged as one of the most pressing challenges in the 21st century, threatening ecosystems, public health and long-term economic sustainability. The rapid industrialization, urbanization, mining, agriculture and infrastructural development witnessed across both developed and developing economies have accelerated environmental damage, evidenced by rising carbon emissions, deforestation, biodiversity loss, and pollution of air, water and soil, loss of climate change, habitat destruction, and soil erosion thereby causing negative social, economic and health effects (Yang et al, 2020). Furthermore, environmental degradation contributes to increasing rural-urban migration and conflict over shrinking natural resources, particularly between farmers and herders. These tensions have evolved into broader national security concerns, affecting social cohesion and undermining national development (International Crisis Group, 2021).

The ecological effects of environmental degradation and climate change are particularly severe in developing countries like Nigeria where limited resources, rapid population growth and weak environmental regulations exacerbate the problem. Nigeria ranks among the countries with the highest rates of deforestation globally, losing approximately 3.7% of its forest cover annually (FAO,2020). The rapid deforestation –driven by logging, agriculture, and urban expansion- leads to severe habitat destruction, biodiversity loss and alteration of local climate systems. Additionally, desertification is encroaching upon fertile agricultural land in northern Nigeria, affecting over 60% of the landmass and threatening the livelihoods of millions of farmers (UNCCD,2022). These environmental hazards degrade water quality, disrupt aquatic life and endanger human health. Contaminated water and poor air quality contribute to a rising burden of diseases such as cholera, typhoid and respiratory infections especially among children and marginalized populations (WHO, 2022).

The Niger Delta region faces the serious menace of water and oil spillage and poor sanitation which lead to health crises, biodiversity loss and conflicts over water resources. This region is one of the most bio diverse ecosystems in West Africa and is heavily contaminated due to recurrent oil spills, with 3000 incidents recorded between 2006 and 2020 (Amnesty International, 2022). The Coastal regions of Nigeria such as Lagos are at risk of sea level rise and increased flooding resulting from climate changes. This rising temperatures and erratic rainfall patterns lead to crop failures, flooding and displacement of communities. Nigeria has recorded significant flooding events arising from erratic rainfall patterns such that 7million people were affected by flood in 2012 while 2013 flood affected over 47000 people (Criminal Law Protection Based on Green Ecological Environment, 2022). Given the severe ecological consequence and their ripple effects on health, security and development, a comprehensive study is urgently needed as this one to tackle the situation at hand.

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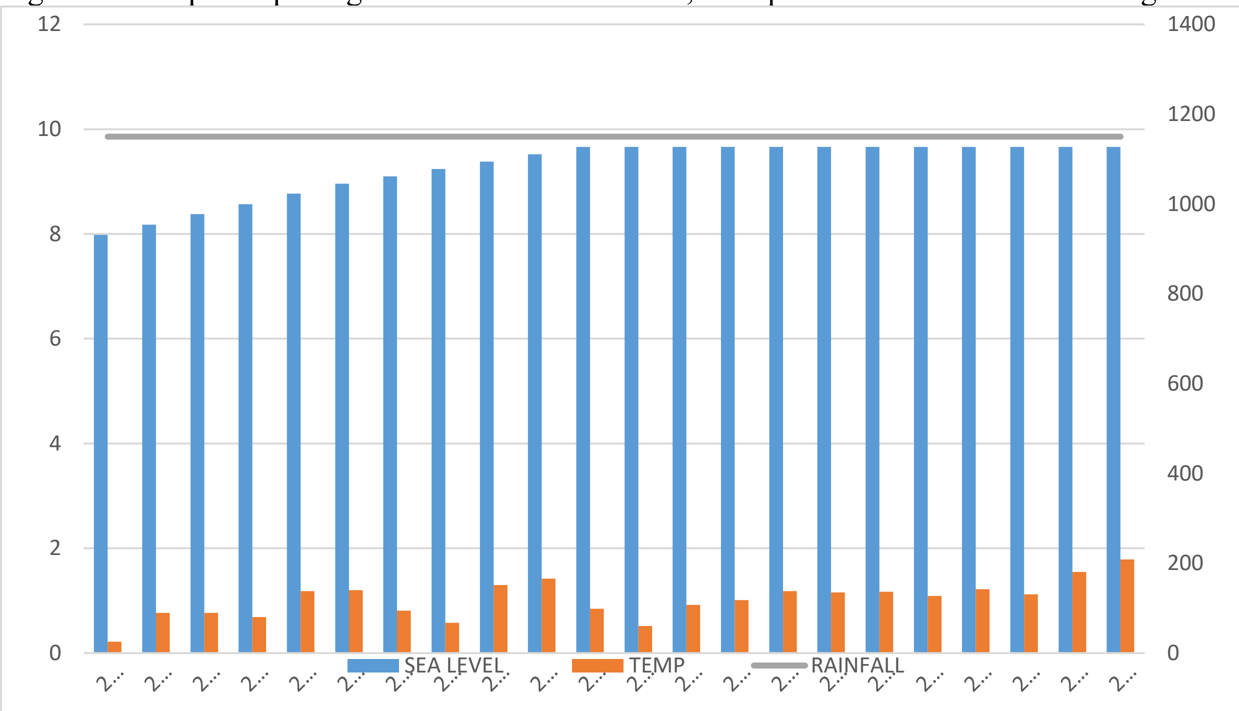
Figure 1: Graph Depicting the Trend of Sea-level, Temperature and Rainfall in Nigeria



Source: Authors computation from WFP, 2023

A critical look at the graph above suggests that Nigeria is experiencing significant climate change impacts, including rising temperature, see level and erratic rainfall patterns (WFP, 2023) The rising temperature and erratic rainfall patterns lead to crop failures, flooding and displacement of communities. The implication on the Nigerian economy is that food insecurity will ravage the country since land degradation and the erratic climate patterns threaten agricultural productivity and invariably lead to increase in hunger and poverty. This incessant climate change culminates into some vicious circle of occurrences very inimical to the Nigerian populace such as health risk, economic strain, social and political instability and weak institutional responses. There is therefore urgent need for a comprehensive study to address the environmental challenges holistically, hence the study on financial development, economic growth and environmental sustainability in Nigeria.

Furthermore, the fundamental drivers of economic expansion in modern economics is the development of the financial sector. A well-functioning system mobilizes savings, allocates capital efficiently, supports innovation and facilitates trade and investment. Over the past decades, many countries- particularly emerging markets have pursued financial liberalization and capital market expansion as a strategy for boosting growth. However, this process also has significant environmental implications. For instance, increased credit availability may finance not only productive economic activities but also environmentally harmful industries such as Coal-based energy, mining and heavy manufacturing (Shahbaz et al, 2023). Simultaneously, economic growth itself has complex effects on the environment. The conventional wisdom posits that at lower levels of development, economic growth typically leads to environmental degradation due to increased industrial activity, energy consumption and weak environment regulations. However, the Environmental Kuznets Curve (EKC) hypothesis suggests that after

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reaching a certain income threshold, societies can invest in cleaner technologies and enforce stricter environmental standards, thereby reducing environmental harm (Grossman & Krueger, 1995). This U-shape relationship implies that economic growth may initially worsen but later improve environmental quality.

The financial sector plays a critical role in mediating this growth-environment relationship. On one hand, financial development can accelerate growth and magnify environmental degradation through increased industrial output and energy use. On the other hand, a mature and regulated financial sector may promote environmental sustainability by allocating capital to green industries, enabling investments in clean technologies and supporting environmental risk assessment through mechanisms like green bonds, ESG (Environment, Social and Governance) ratings and climate risk disclosures (Zhang et al ,2022).

Despite the increasing policy emphasis on green finance and sustainable development, the empirical relationship between financial sector development, economic growth and environmental degradation remains ambiguous and contested. Some studies find that financial development exacerbates environmental degradation by financial polluting industries (Sadorsky, 2010; Omoke et al 2020; Odiahmbo 2020; Abdelhamid et al 2023; Shahbaz 2013; Ali 2015; Ochada et al 2020; Bilgili et al 2025). While others suggest it fosters environmental improvement by promoting efficiency and facilitating green innovation (Tamazian et al 201; Rafindadi et al 2016; Imois 2020; Khan et al 2020; Arif 2024; Sadikov 2025). Similarly, while economic growth is essential for development, its environment consequences depend heavily on the sectorial composition of the economy, institutional capacity and regulatory enforcement.

Recent global developments have added urgency to this debate. The post-COVID recovery has seen massive fiscal and financial interventions that could either promote or undermine environmental sustainability, depending on their orientation. Moreover, climate change has become increasingly visible through extreme weather events, prompting both public and private financial institutions to re-evaluate their roles in sustainability transitions. Financial markets are beginning to price in climate risks and global financial institutions are under mounting pressure to redirect capital flows towards greener investments. For developing and transition economies, the stakes are particularly high. These countries are often heavily reliant on natural resources, face weak institutional and regulatory environments and experience rapid financial and economic changes. Understanding how financial sector development and economic growth affect environmental degradation in this context is essential for crafting effective, context-specific policy interventions.

A good understanding of the distributional influence of financial development and economic growth on environmental sustainability is crucial for formulating policies that balance developmental objectives with ecological protection. The relationship is unlikely to be uniform across all environmental states; for instance, financial development might support environmental quality in low-pollution regimes through innovation financing but exacerbate degradation in high-pollution regimes by facilitating resource extraction and industrial expansion (Odionye, et al., 2024c). Similarly, economic growth could either follow an environmental Kuznets curve trajectory—improving sustainability after surpassing a threshold—or worsen environmental outcomes if structural dependence on polluting sectors persists. Capturing these heterogeneous effects requires an estimation framework capable of addressing asymmetries and regime-specific dynamics. The Quantile Autoregressive Distributed Lag (QARDL) model offers significant value added in this context. Unlike

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conventional mean-based approaches, QARDL estimates the short- and long-run relationships across different quantiles of the dependent variable, thereby revealing how the influence of financial development and economic growth varies under different levels of environmental quality (Cho et al., 2015; Odionye, et al., 2025a). This is particularly relevant for Nigeria, where environmental sustainability indicators exhibit high volatility and spatial heterogeneity due to varying regional economic activities, policy enforcement, and natural resource endowments. By leveraging QARDL, the study can uncover whether financial development's environmental impact is more pronounced in extreme pollution conditions or in cleaner environmental regimes, and whether growth-induced sustainability gains (or losses) are concentrated at specific points in the distribution.

The study is structured as follows, with the exception of the introduction: The second section provides a literature review, the third addresses the methodology, the fourth delves into the conclusions and empirical data, and the fifth wraps up with suggestions for future policy.

LITERATURE REVIEW

Many theories have been applied to explain the connexions between financial development, economic growth and environmental protection.

Environmental Kuznets Curve (EKC): As previously discussed, the EKC hypothesis explains that environmental harm increases as an economy develops, but it decreases once the economy reaches a certain level of income. It has been commonly used to examine the link between economic development and the state of the environment.

Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT): This model explores the effect of human activities on the environment by considering population, affluence and technology. It helps analyse how changes in financial and economic systems affect the environment.

Empirical Review

Zhou et al. (2024) conducted a detailed study to determine the impact of natural resource rents on the environment in Brazil, Russia, India, China and South Africa over the period of 1995 to 2019. The study uses CO_2 and PM2.5 to stand for environmental damage and uses the STIRPAT model to examine the effects of resource exploitation, economic growth, urbanisation and green policies on the environment. It includes the analysis of total natural resource rents, as well as rents for coal, oil, gas, minerals and forests, plus green technology, green finance, renewable energy use and waste management. By applying CCEMG, AMG, FMOLS and PQR, the study found that coal and oil rents lead to greater environmental harm. Similarly, green policy variables help to decrease pollution, mainly in places with high pollution levels. The rise in pollution in BRICS economies indicates that they have not yet reached the stage where pollution decreases with economic growth.

Anochiwa et al. (2022) study how financial development impacts the carbon emissions from consumption in 19 Sub-Saharan African countries, using data from 1995 to 2017. To deal with the effects of distribution, they use MM-QR and discover that financial development leads to

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higher emissions in countries with high carbon emissions. The analysis does not point to the Environmental Kuznets Curve hypothesis being true for the region.

Ridwan et al. (2024) looked at how AI, financial growth and the digital economy influence the environment in G-7 countries from 2010 to 2022 using the Load Capacity Curve (LCC) hypothesis and Method of Moments Quantile Regression (MMQR). The investigation showed that there is a U-shaped link between income and environmental sustainability, as the LCC framework suggests. The load capacity factor (LCF) improved due to the positive effect of AI and financial development on sustainability. Alternatively, LCF was negatively influenced by the digital economy and urbanisation. By testing the results and looking at causality, it was clear that using AI and finance is necessary to address the environmental issues caused by digitalization and cities growing.

Tiwari et al., (2024) examine the relationship between renewable energy, energy innovation, climate change and green finance development with the energy transition in the United States from 2008 to 2022. According to DARDLS, both using renewable energy and promoting energy innovation contribute positively to energy transition and sustainable energy management in the short and long run. In the early stages, green finance development has a small positive effect, but its benefits increase as time goes by. On the other hand, climate change creates more risks for energy transition in the present and future. The authors advise on actions to increase renewable energy, encourage energy progress and introduce green finance to control the risks of climate change in the USA.

Fernández, Haffner and Elsinga (2024) examine the effects on different groups in society of housing renovation policies in the Netherlands, considering subsidies and green taxes. The study analyses how these policies influence the cost of housing for people with different incomes. They analyse the benefits and costs of housing renovation using information from government records and hedonic regression analysis. The researchers consider two approaches: the current system that directly subsidises energy and a new policy that would tax properties based on their energy efficiency. Currently, research suggests that housing tax subsidies are not fair and may favour wealthier homeowners. Alternatively, applying energy-efficiency-related taxation to property could help address issues of regressive taxation and encourage homeowners to improve their properties. It highlights that thinking about housing affordability when making renovation policies is necessary to ensure both the environment and economy are treated fairly.

Dong and Xiao (2024) analyse the way China's carbon emissions trading scheme (ETS) has affected the distribution of wealth in cities from 2013 to 2019, focusing on whether any climate injustices occurred. They use a DID model to analyse the ETS policy and discover that it encourages economic growth in cities. A closer look with a changes-in-changes (CIC) model shows that the ETS policy favours developed cities, making the gap between developed and developing regions wider. Analysis of the mechanism shows that the policy has a stronger positive impact on innovation than its negative effects on foreign investment and industrial structure. However, it increases economic inequalities and raises equity issues in climate policy implementation.

In 2024, Zafar et al. analyze the different ways in which financial development impacts carbon emissions in various ranges, using nonlinear ARDL models and quantile regression. They have found that the impact of financial development on carbon emissions depends on the state of the

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economy. When growth is happening, financial development increases emissions, but it has a lesser effect when the economy slows down. Furthermore, the impact is greater in those areas that emit more carbon. This study points out that policies should address these differences, for example, by increasing green finance when the economy is growing to protect the environment. The study highlights why nonlinear relationships are important in environmental economics.

In this study, Sun et al. (2023) explores the different ways economic growth and renewable energy influence carbon emissions using quantile-on-quantile regression. They use information from 1990 to 2020 to analyse global data. It is shown that carbon emissions respond differently to economic growth and renewable energy, depending on how much carbon each country emits. They prove that different situations of emissions should be considered when making policies to reduce carbon emissions. Ahmad et al. (2022) studies the relationship between financial inclusion and environmental damage by examining data from all over the world between 2004 and 2019. They examine the relationship between financial inclusion and carbon emissions for different ranges of emissions. It is found that financial inclusion can impact the environment differently, depending on the current level of carbon emissions. The results suggest that setting emission limits is necessary when putting together policies that promote financial inclusion and protect the environment.

Baloch, et al., (2021) analyse how financial development, economic growth and ecological footprint are related using quantile regression analysis. They study the panel data collected from 59 Belt and Road Initiative (BRI) countries for the years 1990 to 2016. The research shows that financial development, economic growth, energy consumption, FDI and urbanisation cause the environment to suffer by increasing the ecological footprint. Such findings make it clear that we should implement policies that support sustainable financial and economic activities to help protect the environment.

Dogan, et al., (2025) examine the impact of digital finance on helping the environment in both developed and developing countries. They use quantile regression on data from 2010 to 2019 to understand how different levels of carbon emissions are affected by digital financial services. The study found that digital finance affects the environment differently for countries with different emission levels, so specific policies are needed to address these differences. The study adds to the existing research on digital finance and environmental sustainability, highlighting that each context requires a unique strategy for using digital finance to protect the environment.

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METHODOLOGICAL FRAMEWORK

Data Description

The study utilizes quarterly series covering the period from 1990 to 2022 to explain the response of environmental sustainability to varied changes in financial sector development and economic growth. The study's data were collected from the World Bank data storehouse based on its objectives. Table 1 offers a comprehensive elucidation of the series.

Table 1: Data descriptions

Variables	Representation	Unit of measurement	Source
Gross domestic product per capita	GDP	Gross Domestic Product per capita at 2010 constant prices (Local currency)	WDI
CO2 Emission	CO2	World Bank Definition (Difference between sources of funds and uses of funds)	WDI
Ecological Footprint	EFP	Ecological resource use and resource regeneration capacity (index)	YUEFI
Financial Development	FID	Local Credit to private sector (% GDP)	WDI
Energy Use	ECN	Energy used (kg of oil equivalent per capita)	WDI
Urbanization	URB	Urban population (% of total population)	WDI

Note: YUEFI denotes York University Ecological Footprint Initiative & Global Footprint Network, WDI represents world development indicator at world bank repository.

Model Specifications

Following the Kuznet environmental curve (EKC) hypothesis and in line with relevant past studies (Busavo & Hooi 2022; Ekundayo & Chidi, 2022), the study considers the functional form:

$$LENS_t = b_0 + b_1LFID_t + b_2LGDP_t + b_3LGDP^2{}_t + b_4LECNt_t + b_5URB_t + \varepsilon_{it}\varepsilon_{it} \quad (1)$$

Where L stands for the natural log of the series, ENS, FID, GDP, GDP^2, ECN, POP represent environmental sustainability, financial development, gross domestic product, square of gross domestic product, energy consumption and urban population, respectively. Additionally, the subscript t denotes the time period while ε indicates the stochastic error term. In this study, two diverse measures of environmental sustainability (carbon dioxide emission (CO2) and ecological footprints (EFP)) are employed.

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Estimation Technique

Given that the objective of the study is to ascertain the distributional influence of financial development and economic growth on environmental sustainability in Nigeria, the study adopted the quantile regression version of Autoregressive Distributed Lag (QARDL) framework. To estimate how environmental sustainability reacts to the listed explanatory variables at different quantiles, we specify to the generalized form of the quantile model. Following Huang, et al., (2017) and Mazucheli, et al., (2021) and consistent with Koenker and Bassett (1978), the study specifies the model in its general form

$$\mathrm{Y}_t[\tau/\mathrm{X}_t,\eta(\tau)] = \mathrm{X}_t\eta(\tau)\ldots \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where $\eta(\tau)$ represents the vector of coefficients related to τ^{th} quantile. The model in Eqn. 2 assumes a linear function conditioned upon the quantile of the reaction of Y given X. According to Koenter and Bassett (1987) and Koenker (2005), there are several advantages of quantile regression as it permits the estimation of least square deviation (LAD) parameter that is consistent with the conditional median of the reaction variable. It explains how the median or the τ^{th} percentile of the reaction variable is driven by the explanatory variable. It provides a robust model as it does not warrant strong sinewy distributional assumption. The QARDL framework as developed by Cho et al. (2015) utilized the synthesis of Koenker and Bassett (1978) quantile regression model and the Pesaran and Shin's (1998) autoregressive distributed lag (ARDL) model. The generalized ARDL framework is given as

$$Y_t = \beta_0 + \sum_{i=1}^{m}\delta_i\Delta Y_{t-i} + \sum_{i=0}^{n}\eta_i\Delta Z_{t-i} + \sigma_t Z_t + \varphi \mathrm{ect}_{t-1} + \varepsilon_t \quad (3)$$

where Y and Z represent the explained and explanatory factors respectively, the first two-term denotes the short-term parameters, the third-term represents the long-term coefficient while φ measures the degree of convergence, ε is the white noise stochastic term that is independently and identically distributed. The generalized form of the QARDL according to Cho et al. (2015) is expressed in Eqn. 4

$$Y_t[\tau / Z_t,\eta(\tau)] = \beta_0(\tau) + \delta(\tau)Y_t + \sum_{i=1}^{m}\delta_i(\tau)Y_{t-i} + \sum_{i=0}^{n}\eta_i(\tau)Z_{t-i} + \varepsilon_t$$

$$\text{where } \delta_i(\tau) = \sum_{i=0}^{m}\delta_i \text{ and } \eta(\tau) = -\sum_{i=1}^{n}\eta_i(\tau) \quad (4)$$

In Eqn. 4, $\eta(\tau)$ represents the vector of coefficients related to τ^{th} quantile, whereas the others are as described in Eqn. 3. Eqn. 3 expresses the short-run QARDL framework. The long-run framework is expressed in Eqn. 5:

$$Y_t = \sigma(\tau) + \lambda(\tau)Z_t + \varepsilon_t(\tau)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

where $\sigma(\tau) = \delta(\tau)\left(1-\sum_{i=1}^{m}\delta_i(\tau)\right)^{-1}$ and $\lambda(\tau) = \eta_i(\tau)\left(1-\sum_{i=1}^{m}\eta_i(\tau)\right)^{-1}$; ε_t is a stationary process given by

$(\Delta Z_t,\ \varepsilon_t(\tau),\ \Delta Z_{t-1},\ \varepsilon_{t-1}(\tau),\ldots)$

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The QARDL's model based on the functional form in Eqn. 1 is expressed in Eqn. 6 as:

$$\Delta LENS_t(\tau) = \beta_0(\tau) + \delta_1(\tau) LENS_{t-1} + \sum_{i=0}^{m} \delta_2(\tau)\Delta LENS_{t-1} + \sum_{i=0}^{n1} \eta_1(\tau)\Delta LFID_{t-i} + \sum_{i=0}^{n2} \eta_2(\tau)\Delta LGDP_{t-i} + \sum_{i=0}^{n3} \eta_3(\tau)\Delta LGDP^2_{t-i} + \sum_{i=0}^{n4} \eta_4(\tau)\Delta LECN_{t-i} + \sum_{i=0}^{n5} \eta_5(\tau)\Delta LURB_{t-i} + \varphi_1(\tau) LFID + \varphi_2(\tau) LGDP + \varphi_3(\tau) LGDP^2 + \varphi_4(\tau) LECN + \varphi_5(\tau) LURB + \phi(\tau) ect_{t-1} + \varepsilon_{it} \quad (6)$$

The variables in Eqn. 6 are as described in Eqn. 1, ect is the error correction parameter, $\Delta =$ difference operator; m, n1, n2, n3, n4, and n5 denote the ideal number of lags chosen based on lag length information criteria, ε = white noise error term. The determination of the series integration order is crucial since QARDL's reliability is limited to series integration orders of not exceeding 2. This study employs the Canova-Hansen test, which incorporates the seasonal component in unit root analysis, alongside the conventional augmented Dickey-Fuller (ADF) unit root test (URT). This ensures the utilisation of the stationary processes I (1) and I (0).

EMPIRICAL OUTCOMES

Descriptive statistics

Broadly speaking, descriptive statistics are used at the start of every scientific study to lay the groundwork for more complex computations. Consequently, summary statistics were utilised for the relevant series in this study. This test primarily identifies the distribution's characteristics and the behavioural trends of the series, along with other relevant factors. Specifically, the data from the descriptive statistics shows whether or not the series are distributed normally. Consequently, a summary of the test results is shown in Table 2.

Table 2: Descriptive Statistics

	CO2	ECN	EFP	FID	GDP	GDP2	URB
Mean	0.169	183.50	0.188	2.593	408.24	207049.6	10.14
Maximum	0.230	199.98	0.208	5.091	810.71	657245.8	13.46
Minimum	0.122	169.01	0.154	1.160	73.49	5400.44	7.37
Skewness	0.378	-0.075	-0.259	0.768	-0.015	0.679	0.189
Kurtosis	1.851	2.216	2.362	3.286	1.850	2.830	1.703
Jarque Bera	10.3***	3.502	3.71	13.43***	7.27**	10.32***	10.03***

Note: ***(**) represent statistically significant at 1%(%) significance levels, respectively

Apparently, based on the Jarque-Bera statistics, Table 2 show that, in exception of energy consumption (ECN) and economic footprint (EFP), all the series deviates from the normal distribution. These results, which yield robust estimates in the face of anomalous distribution, notably justify the selection and use of quantile-based ARDL estimation approach (Koenker and Bassett, 1987; Cho et al, 2015, Odionye, 2023a; 2023b; 2024a; Odo, et al., 2025).

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BDS Statistics

The heterogeneous characteristic of the series was supported by the estimation of Broock et al. (1996), commonly referred to as the BDS test. The estimation posits that the series demonstrates independent and identically distributed (i.i.d) residuals, whereas the alternative hypothesis suggests that the residual series displays an anomaly from conventional behaviour, indicating nonlinear reliance.

Table 3: Summary of BDS Statistics

Measurement	Series						
(m)	LENS1	LENS2	LFID	LGDP	LGDP2	LECN	OPSS
2	0.176***	0.159***	0.173***	0.191***	0.192***	0.181***	0.207***
3	0.293***	0.257***	0.286***	0.321***	0.321***	0.301***	0.351***
4	0.369***	0.313***	0.361***	0.408***	0.409***	0.379***	0.452***
5	0.420***	0.343***	0.409***	0.464***	0.464***	0.425***	0.524***
6	0.455***	0.357***	0.439***	0.499***	0.498***	0.453***	0.576***

******(**) signifies rejection of the null hypothesis of linearity at 1%(5%) level of significance***

Table 3 shows that the alternative hypothesis was accepted while the null hypothesis of the BDS in the series was rejected. The findings confirm the heterogenous features of the data series, necessitating the application of a heterogenous approach (Odionye, et al., 2023b; Odionye, et al., 2025a; 2025b).

Unit Root Test (URT)

To ascertain the model series integration order, the study employed a number of robust stationarity estimation techniques, such as the Canova-Hansen seasonality unit root test (CH_ URT) to account for seasonality, Zivot-Andrews (ZA_URT) to account for structural breaks inherent in long series, and the conventional augmented Dickey-Fuller (ADF). The choice of these arrays of unit root procedures is to ensure that level- and difference-stationary series are used, ensuring robust and reliable estimates (Cho et al., 2015, Odionye, et al., 2019, 2023c, 2024a).

The procedures hypothesize unit root (non-stationary) at the designated seasons and structural breaks for CH_URT and ZA_URT respectively. The outcomes of the URTs, in brevity, are presented in Table 4.

Table 4: Unit Root Tests Result

Panel A: Canova-Hansen Seasonal Unit Root Test													
Variables	**J_LM**	**1%**	**5%**	**10%**	**S1**	**Crit**	**S2**	**Crit**	**S3**	**Crit**	**S4**	**Crit**
LENS1	1.53	1.35	1.01	0.85	1.32	0.47	1.32	0.47	1.35	0.47	-	-
LENS2	0.8**	1.35	1.01	0.85	0.5**	0.75	0.5**	0.75	0.4**	0.75	-	-
LFID	1.2**	1.35	1.01	0.85	1.1**	0.75	0.6**	0.75	0.4**	0.75	-	-
LGDP	1.3**	1.35	1.01	0.85	1.4	0.75	1.09*	0.75	1.16	0.75	-	-
LECN	1.32	1.35	1.01	0.85	1.28	0.75	1.56	0.75	1.45	0.75	-	-
LURB	3.37	1.35	1.01	0.85	2.08	0.75	2.09	0.75	2.11	0.75	-	-

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Panel B: Conventional and Structural Breaks URTs

	ADF_URT					Zivot-Andres unit root test (ZA_URT)						
Variables	**Level**	**1st diff**	**2nd diff**	**I (d)**	**Lag**	**Level**	**B-P**	**Lag**	**1st diff**	**B-P**	**Lag**	**I(d)**
LENS1	-1.27	-4.29**		1	8	-2.81	12Q1	2	-6.87**	13Q4	2	1
LENS2	-2.50	-7.8**		1	9	-5.78**	15Q3	4				0
LFID	-5.5**			0	5	-6.07**	08Q9	5				0
LGDP	-1.94	-4.11**		1	4	-5.07**	15Q4	3				0
LECN	-1.44	-3.53**		1	8	-1.98	19Q3	2	-6.87**	20Q1	4	1
LURB	-1.23	-5.26**		1	4	-0.98	11Q4	6	5.26**	17Q4	5	1

***** indicates LM test (both joint and individual seasons) signifying the rejection of null hypothesis of unit root at the specified seasons/with breaks at 5% level of significance. J_LM represents joint LM statistic; S represents seasons and Crit connotes the critical vale for individual seasons; BP represents break period; I(d)signifies the order of integration***

Panel A of Table 4 reveals level-stationary in LENS2, LFID and LGDP at the joint and diverse seasons, while the other series indicate level non-stationary across diverse seasons. The outcomes from the ZA_URT and ADF further confirmed the fractionally integrated series. Specifically, ADF indicates that, except LFID, all the series are difference-stationary series while in the case of the ZA_URT, LENS1, LECN and LURB are difference-stationary series. However, the other series are level-stationary series. This obvious upshot rationalizes the use of QARDL estimation procedures since the series are fractionally integrated at diverse seasons and structural breaks (Cho et al 2015; Odionye, et al., 2023c). The study, in line with Cho et al (2019), adopted the Bound cointegration procedure as well as the two-step cointegration method in order to create the projected residual after re-paramatized estimation to evade the singularity problem. The outcomes of the cointegration, in brevity, are displayed in Table 5.

Cointegration Test

Considering that the pre-requisite for cointegration in QARDL model is satisfied, the study estimated both the bound cointegration within the framework of. QARDL and the two-step cointegration and the summary of results are presented in Table 5.

Table 5: Bound Cointegration Test

Model	F-Statistics	t-Statistics	5% level	I(0)	1(1)	Remark
Panel A: Bound Cointegration						
Model 1	3.69**			2.56	3.49	Cointegrated
Model 2	5.5**	4.96**	7.1***	2.56	3.49	Cointegrated
Panel B: Two-Step Cointegration						
Residual_1		5.10***	-2.89			Cointegrated
Residual_2		-3.17**	-2.88			Cointegrated

Note: ***(**) denotes 1% (5%) level of significance

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Table 5 revealed a strong long run interaction between environmental sustainability (ecological footprint and CO2), economic growth, financial deepening and other relevant covariates given that the reparametized residual is level stationary. Thus, the study estimated the QARDL-ECM result.

Lag Length Selection

The ideal lag value for the series was determined using the lag length information principles, and the findings are shown in Table 6.

Table 6. Lag length Choice based on Information Criteria

Lag	Logl	LR	FPR	AIC	SC	HQ
0	409.3126	NA	6.03e-11	-6.505042	-6.368576	-6.449606
1	1870.670	2757723	6.25e-21	-29.49468	-28.53942	-29.10663
2	2529.012	3.431754*	3.12e-24*	-37.20988*	-32.16066*	-35.15877*
3	2142.182	46.06922	2.54e-22	-32.71262	-30.11978	-31.65934
4	2157.715	24.80199	3.60e-22	-32.38250	-28.97087	-30.99661
5	2284.451	190.1037	8.59e-23	-33.84598	-29.61556	-32.12748
6	2529.012	437.3926	2.18e-22	-32.85451	-31.08046	-32.13385

* denotes lag order chosen by the condition

Table 6 divulges lag 2 as the ideal lag value based on the information condition, Consequently, the QARDL is estimated based on lag 2.

Quantile Autoregressive Distributed Lag (QARDL) Outcome

As mentioned earlier, the framework created to ascertain the response of environmental sustainability (ecological footprint and CO2) to heterogeneous changes in financial sector development, economic growth and other theoretical-related covariates in Nigeria is the QARDL approach. To maintain brevity, the most relevant empirical findings are encapsulated in Table 7.

Table 7 Summary of Quantile ARDL Outcomes

	Quantiles								
Panel A1: Short-Term Outcomes (CO2 Model)									
Variables	**10th_qle**	**20th_qle**	**30th_qle**	**40th_qle**	**50th_qle**	**60th_qle**	**70th_qle**	**80th_qle**	**90th_qle**
Δ(LENS1(-1))	0.48**	0.46**	0.45**	0.45**	0.42**	0.35**	0.34**	0.31**	0.27**
Δ(LFID)	0.0009	0.029	0.008	0.038	0.063**	0.069**	0.106**	0.14**	0.19**
Δ(LFID (-1))	-0.002	-0.033	0.002	0.005	0.005	0.007	0.009	0.016*	0.017*
Δ(LGDP)	0.133**	0.105**	0.118**	0.094*	0.102*	0.148*	0.162**	0.219*	0.157*
Δ(LGDP(-1))	0.043*	0.031*	0.021	0.014	0.019	0.009	0.017	0.013	0.015
Δ(LGDP2)	-0.12**	-0.16**	-0.18**	-0.18**	-0.22**	-0.24**	-0.32**	-0.33**	-0.018*
Δ(LECN)	1.45**	1.589	1.817*	1.818**	1.678**	1.707**	1.695**	1,79**	2.046**
Δ(LURB)	10.18*	8.97*	10.02**	8.99**	7.24**	7.26**	6.70*	6.01*	6.048
ECT1(-1)	-0.085**	-0.065**	-0.057**	-0.061**	-0.064**	-0.068**	-0.067*	-0.097*	-0.159**

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SR_A1_Validity Test: RRT [3.38] SQT [21.35] QSET [39.26]****									
Panel A2: Short-Term Outcomes (Ecological Footprint Model)									
Δ(LENS2(-1))	0.49*	0.47**	0.41**	0.34**	0.37**	0.39**	0.40**	0.42**	0.50*
Δ(LFID)	0.126**	0.115**	0.136**	0.153**	0.142**	0.158**	0.157**	0.14**	0.214**
Δ(LFID (-1))	0.016	0.010	0.012	0.001	0.005	0.003	0.003	0.003	0.04**
Δ(LGDP)	0.130**	0.153**	0.148**	0.208**	0.292**	0.274**	0.331**	0.31**	0.38**
Δ(LGDP(-1))	0.135**	0.209**	0.221**	0.220**	0.301**	0.317**	0.343*	0.35**	0.430**
Δ(LGDP2)	-0.09**	-0.09**	-0.11**	-0.21**	-0.31**	-0.31**	-0.31**	-0.32**	-0.35*
Δ(LECN)	0.161	0.046	0.007	0.040	0.095*	0.103*	0.138**	0.17**	0.254**
Δ(LURB)	0.039	0.022	0.022	0.003	0.009	0.019*	0.027**	0.03**	0.082**
ECT2(-1)	-0.117**	-0.109**	-0.098*	-0.058	-0.051	-0.066*	-0.075*	-0.09**	-0.156**
SR_A2_Validity Test: RRT [0.12] SQT [46.81] QSET [37.90]** WT [36.32]****									
Panel B1: Long-Term Outcomes (CO2 Model)									
LFID	0`.064	0.098	0.098	0.086	0.107	0.121**	0.15**	0.19**	0.21**
LGDP	0.013	0.017	0.018	0.029	0.029	-0.01	-0.02**	-0.04**	-0.07**
LGDP2	-0.02**	-0.06**	-0.06**	-0.101	-0.01**	-0.18**	-0.23**	-0.26**	-0.31**
LECN	0.022*	0.035	0.048	0.051	0.061	0.064*	0.056	0.067	0.072
LURB	0.061	0.052	0.051	0.059	0.085	0.096	0.099	0.097	0.096
SR_A2_Validity Test: RRT [3.02] SQT [34.01] QSET [27.90]****									
Panel B2: Long-Term Outcomes (Ecological Footprint Model)									
LFID	0.041	0.035	0.065	0.086	0.097**	0.101**	0.15**	0.31**	0.34**
LGDP	0.043	0.047	0.048	0.049	0.049	0.05*	-0.054*	-0.07**	-0.09**
LGDP2	-0.02**	-0.04**	-0.05**	-0.06*	-0.08**	-0.09**	-0.14**	-0.27**	-0.48**
LECN	0.19**	0.212	0.282	0.312	0.38**	0.37**	0.53**	0.62**	0.78**
LURB	0.316	0.453	0.461	0.496	0.565	0.476	0.679	0.687	0.786
LR_B2_Validity Test: RRT [2.31] SQT [36.11] QSET** [56.24]**									

***Note:* **(*)** signifies 1%(5%) level of significance; *.RRT represents Ramsey RESET test model specification, SQT epitomizes Slope Quantile test, QSE represents Quantile Slope Equality test for quantile symmetry.*

Table 7 summarises the results from the QARDL. One interesting outcome is that environmental quality [for both CO2 (Δ(LENS1(-1)) and ecological footprint (Δ(LENS2(-1))] is self-reinforcing across all quantiles, among other intriguing findings. The fact that environmental quality has a positive and strong association between its historical and present values seems to prove this consequence. The implication of this upshots is that an improvement or otherwise in the current state of the environment depends on the past environmental situation.

It is essential to note that, across diverse quantiles especially at the upper quantiles, the short-term outcome (Panel A1 and Panel A2) regarding the mentioned regressors shows that financial development (Δ(LFID)) significantly increases the country's carbon emission (Panel A1) and ecological footprints (Panel A2), thereby worsening its environmental quality. The size of the coefficient suggests that LFID has a distributional impact on environmental impact, with the influence deteriorating at an increasing pace along the upper quantiles. For example, at the middle and higher quantiles (50^{th}_qle, 60^{th}_qle, 70^{th}_qle, 80^{th}_qle, and 90^{th}) of the carbon emission distribution, elevated financial development increases the value by 0.063%, 0.069%,

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0.106%, 0.14%, and 0.19%, respectively. Similarly, at all quantiles (10th_qle, 20th_qle, 30th_qle, 40th_qle, 50th_qle, 60th_qle, 70th_qle, 80th_qle, and 90th_qle) of ecological footprint distribution, increased financial development increases the value by 0.126%, 0.115%, 0.136%, 0.153%, 0.142%, 0.158%, 0.14%, 0.214% respectively. These obvious outcomes demonstrate that financial development significantly deteriorates environmental quality in the country; as the financial sector expands, CO2 emissions and ecological footprint increase, thereby undermining environmental quality in Nigeria. The results provide substantial support for this hypothetical view. Likewise, the long-term outcomes (Panels B1 and B2) reveal that, for every 1% increase in financial development at the middle and upper quantiles (60th_qle. 70th_qle, 80th_qle, 90th_qle), the country's environmental quality worsens by 0.121%, 0.15%, 0.19%, and 0.21 via emission, 0.097%, 0.10%, 0.15%, and 0.43% through ecological footprints respectively. 0.29%, and 0.31%, respectively. The results of this study are in agreement with those of several other studies conducted in West Africa, SSA, Malaysia, and Brazil, including those of Nusah et al., (2022), Odionye, et al., (2024a), Ye et al, (2020), Nwani and Omoke (2020), and Boutafeh and Saadaoui (2020).

The findings concerning the economic growth variable (LGDP) and its square (LGDP2) support the inverted U-shaped proposition, indicating that at early stages of development, increased economic growth worsens environmental quality. However, at a subsequent stage of economic advancement, a positive relationship emerges between society and the environment, leading to a decrease in environmental degradation. The evident result is illustrated by the substantial and significant effect of LGDP on environmental via increased emission of CO2 and elevated ecological footprint across all quantiles in the short-run. In specific terms, at all quantiles (10th_qle, 20th_qle, 30th_qle, 40th_qle, 50th_qle, 60th_qle, 70th_qle, 80th_qle, and 90th) of the carbon emission distribution, economic growth increases the value by 0.133%, 0.105%, 0.118%, 0.094%, 0.102%, 0.148%, 0.162%, 0.219%, and 0.157%, respectively. Similarly, at all quantiles (10th_qle, 20th_qle, 30th_qle, 40th_qle, 50th_qle, 60th_qle, 70th_qle, 80th_qle, and 90th_qle) of ecological footprint distribution, increased financial development increases the value by 0.130%, 0.153%, 0.148%, 0.208%, 0.292%, 0.274%, 0.331%, 0.310%, and 0.38%, respectively. However, in the long-run, it demonstrates mixed outcomes as economic growth at lower and mid quantiles increases CO2, but at upper quantiles (70th_qle, 80th_qle, and 90th_qle) reduces CO2 and hence improves environmental quality, supporting the U-shaped proposition. The long-run outcome for the ecological model is similar to that of CO2. This means that irrespective of the environmental measure, be it CO2 or ecological footprint, the growth effect strongly supports the inverted U-shaped curve. These results correspond with those of Shahbaz et al. (2014) for Tunisia, Rafindadi (2016) and Odionye, et al., (2024a) for Nigeria, Ekundavo and Chidi (2020) for several African nations, Khan et al. (2020) for Pakistan, Marques et al. (2018) for Azerbaijan, and Farhani et al. (2014) as well as Busavo and Hooi (2022) for 92 countries. Shahbaz et al. (2014) discovered that a decrease in the square of GDP correlates with an increase in CO2, while an increase in GDP corresponds with a rise in CO2. The findings also suggest that urbanisation (LURB) have a minimal impact on environmental sustainability in the region.

Regarding energy consumption (LECN), the upshots indicate that the impact of LECN is heterogeneous. Energy consumption exhibits significant increasing effects at various quantiles, where it substantially elevates CO2 in all quantiles but in the case of ecological footprints, it elevates it at middle and upper quantiles (50th_qle – 90th_qle). This underscores that elevated energy consumption in the country substantially amplifies environmental degradation. This

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result implies that nations with high energy consumption face elevated carbon dioxide emissions, resulting in environmental sustainability challenges. This outcome substantiates the findings of Rafindadi & Usman (2019) for South Africa, Mohiuddin et al. (2016) for Pakistan, Asumadu-Sarkodie & Owusu (2016) for Benin, Shahbaz et al. (2014) for Tunisia, and Rafindadi (2016) and Odionye et al., (2024a) for Nigeria.

CONCLUSION AND POLICY RECOMMENDATIONS

This study used the innovative QNRDL model to analyse the distributional impact of financial development and economic growth on environmental quality in Nigeria. By establishing the distributional link between the series based on the magnitudes, the work makes a distinctive contribution to the current literature. The QARDL results reveal that environmental quality in Nigeria is self-reinforcing, with past environmental conditions exerting a significant influence on present outcomes. While this persistence implies that improvements in environmental quality can be sustained over time, it equally suggests that environmental degradation, if left unchecked, may become entrenched. Financial development consistently and significantly deteriorates environmental quality in both the short and long term, as evidenced by its positive impact on CO_2 emissions and ecological footprints across most quantiles—particularly at middle and upper quantiles where the effect intensifies. This confirms the distributional nature of financial development's environmental impact, indicating that economic expansion through financial deepening has been accompanied by higher environmental costs. The findings on economic growth support the Environmental Kuznets Curve (EKC) hypothesis, showing that environmental degradation initially rises with growth but eventually declines at higher levels of income. This transition point, however, appears to occur only at upper quantiles, suggesting that Nigeria is still in the earlier stages of the EKC trajectory. Energy consumption significantly worsens environmental quality, with its effects being more pronounced at middle and upper quantiles for ecological footprint and across all quantiles for CO_2 emissions. Urbanization, by contrast, exerts minimal influence on environmental sustainability. Overall, the results underscore that without targeted policy interventions, financial development and energy consumption will continue to undermine environmental quality, delaying Nigeria's transition toward a sustainable growth path.

The study, drawing from the empirical outcome, recommends as follows:

Green Financial Development Policies: The government should as matter of urgency introduce environmental risk assessments and sustainability criteria in financial sector lending and investment decisions and incentivise green financing products such as renewable energy loans, sustainable infrastructure bonds, and environmentally responsible venture capital. Government should strengthen environmental regulations for industries financed through the banking and capital markets to mitigate the negative environmental effects of financial deepening.

Accelerating the EKC Transition: Government should channel economic growth toward sectors with lower carbon intensity through targeted tax incentives and subsidies. Also policy to promote clean technology adoption, particularly in manufacturing, energy, and transport, to speed up the turning point of the EKC for Nigeria should be put in place.

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Energy Transition Strategies: Expand investments in renewable energy sources (solar, wind, hydropower) to reduce dependence on fossil fuels. Implement progressive carbon pricing or energy taxes to discourage excessive fossil fuel use while funding clean energy projects. Upgrade energy efficiency standards for industries, buildings, and transport systems to curb emissions without constraining economic activity.

Long-term Environmental Planning: Government should establish a national environmental quality monitoring framework that tracks both CO_2 emissions and ecological footprints across sectors and regions. Integrate environmental sustainability goals into Nigeria's medium- and long-term development plans, ensuring policy coherence across energy, finance, and industrial strategies.

Regional and Global Collaboration: Engage with regional bodies in West Africa to harmonise environmental policies and share best practices on sustainable finance and clean energy adoption. Leverage international climate finance mechanisms (e.g., Green Climate Fund) to fund low-carbon projects and climate adaptation measures. By aligning financial development, energy policy, and economic growth strategies with environmental objectives, Nigeria can reverse its current trajectory of environmental degradation while sustaining economic progress.

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