FINANCIAL DEVELOPMENT, URBANIZATION AND THE ENVIRONMENTAL NEXUS IN NIGERIA: A NON-LINEAR ANALYSIS

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ABSTRACT

This paper examines the determinants of carbon dioxide (CO2) emissions by analysing the consequences of financial development (FD) and urbanization (URB) accompanied by economic growth (RGDP) in Nigeria over the period 1986-2022. The study used nonlinear autoregressive distributive lag (NARDL) model posing the asymmetry aspect that can happen among financial development, urbanization and economic growth which movements in either of the variables. The analysis establishes the asymmetric effect of URB, FD and RGDP shocks on CO2 emissions both in the short run, while FD and RGDP shocks impacted CO2 emission in the long run. Moreover, RGDP contributed significantly to CO2 emissions both in the short- and long-run. The study also fulfils to a large degree the existence of EKC associating the unilateral (inverted U shape) connection among FD, RGDP and CO2 emissions in Nigeria. Furthermore, the error correction model confirms a short-run relationship among the variables. Finally, the study proposes the implementation and use of clean energies and technologies are vital for controlling environmental degradation in Nigeria.

Keywords: Carbon emission, financial development, Nigeria, nonlinear ARDL, urbanization.
JEL CLASSIFICATION: C22, O44, P346, Q56

1. INTRODUCTION

Economic activities that are targeted toward economic growth have led to environmental risks, leading to diverse research areas in environmental economics and sustainability that are controversial among environmental scholars (Dinda, 2004; Lorek & Spangenberg, 2014; Merino-Saum et al., 2020). Economists and environmentalists globally have contributed to the literature to understand the economic growth, financial development, and the environment nexuses (Shoaib et al., 2020). Many research and inter-governmental initiatives are being made at the global level to provide answers to mitigate the effects of climate change and its inherent repercussions while boosting global development. While the solution of current problems at global scale gave an impetus to the creation of the United Nations Sustainable Development Goals (SDGs). One of the greatest successes of the second UN Conference on Sustainable Development was regarding the adopting of SDGs (the sustainable development goals) which were established at the original UN Conference on the Human Environment in 1962. The approved goals by the United Nations General Assembly session held in September 2015 and the implementation of the 2030 target is scheduled to happen in year 2020 (UN General Assembly, November 2015).

The success of the UN SDGs, mainly SDG3 - SDG15 – healthy life and well-being, clean water and sanitation, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land – demands a unique action to counter climate change / global warming Environmental deterioration and substantial environmental disruption to human existence and global economic growth are both caused by global warming (Appannagari, 2017). However, with increased economic activity and migration to cities as a result of urbanization and, by extension, globalization, the environmental effects might be disastrous if ignored or left unattended. These plummeted researchers claim that excessive greenhouse gas emissions are to blame for the issue of global warming in an attempt to determine how to mitigate the challenge (Adeleye et al., 2021; Jiang & Ma, 2019). Global warming is a serious challenge encountered across all countries of the world and not peculiar to one region as carbon emissions (CO2) are a culprit of climate change or global warming while the responsibility of sanitizing the climate and truly realising a controlled-carbon economy remains farfetched (Bandh et al., 2021; Nukusheva et al., 2021). CO2 emissions as a result of human activities are currently higher than it has been in the history of mankind as current facts exhibit proof that world CO2 emissions became 150 times higher in 2011 than 1850 (World Resource Institute [WRI], 2014).

According to the WRI (2014), after 1850, the United Kingdom became a major CO2 emitter, with emissions about six times those of America, the second-highest emitter. France, Germany, and Belgium rounded up the top five emitters. China was the sector's greatest emitter in 2011, followed by the United States, India, Russia, and Japan. America became the world's second-largest emitter each year, with emissions in 2011 being 266 times more than in 1850, with other nations following similar trends, increasing their emissions over time. However, certain trajectories look extremely unusual during distinct historical times.

Consequently, the IEA (2021) asserts that although the world experienced some of the greatest level of carbon dioxide emissions ever recorded in history (36.3 billion tonnes) essentially as a result of the global economy rebounding at a very rapid rate from the COVID-19 crisis, the recovery heavily relied on coal as the world's principal power source. Indeed, the IEA declared that in 2021 CO2 emissions went up globally by more than 2 billion tons. This means the amplification of emission burdens of overall greenhouse gases compared to the minimization of emissions observed in the previous year due to the COVID-19 pandemic. Following the slowdown in demand recovery in 2021, unstable weather conditions and energy market exacerbated the situation with higher natural gas prices and more coal burning despite record output growth from renewable power sources (Aguirre-Villegas & Benson, 2022, Gajdzik et al., 2024, Hussain et al., 2023).

Financial development (FD) is a pertinent variable in the modern economy, as it is in every economy across the world. It is also a significant yardstick for measuring the progress of a state. Financial development influence on energy conservation is critical and should be investigated, as it indirectly impacts preserving energy and carbon emissions (Nasreen & Anwar, 2015). Development occurs in nations such as China, where FD is promoted. The volatility of stock prices and trading volume is especially noticeable, demonstrating the explosive growth of China's stock exchange industry. Furthermore, China is becoming increasingly interested in climate action. China, as a major global economy and carbon emitter, is taking responsibility and participating in global climate governance. The degree of development and economic circumstances of China's provinces, on the other hand, differ. According to empirical evidence, nations with more stable financial markets have cleaner ecosystems than countries with undeveloped financial markets. As a result, there is a rather strong link between FD and the environment since the financial sector influences the environment through numerous routes. To begin, more financial activity can promote general growth, which has a knock-on effect on the environment, as demonstrated by the environmental Kuznets curve (EKC).

Financial development increases the volume of energy consumption at an industrial scale, and that is capable of increasing or decreasing emissions of carbon –all of these depend on the mix of energy. Also, the allocation of credit to investments depends on the financial development level of a country. Firms that use up and emit high carbon will not have access to available resources to discourage their activities, while funds released to firms that are less carbon-emitting (Dasgupta et al., 2001; Mesagan et al., 2018). Also, financial development may intensify environmental challenges via enterprises that only contribute through bad practices while producing (Ahmad et al., 2018), as well as the technology used in production can be affected by financial institutions giving out more loans to big companies or heavy industry firms in an effort to boost the production scale (Ahmad et al., 2018; Brännlund et al., 2007; Cole et al., 2005).

The urbanisation effect is of the essence as advancement occurs, preservation of the environment becomes imperative and societies seek alternative ways to become more environmentally sustainable (Mensah, 2019), due to the exodus of the population from the rural metropolis to cities to search for greener pastures (Ashogbon et al., 2023; Bukar et al., 2021; Halsey, 2009; Nwalusi et al., 2022). Nigeria is the centre of this inquiry because it is the acclaimed giant of Africa concerning population and productivity, it relies heavily on fossil fuels to provide energy for the inhabitants. Furthermore, Nigeria is Africa's greatest crude oil producer, and statistics suggest that Nigeria produces the most gas flaring in Africa (see Akinola, 2018; Okoye et al., 2022; Oni & Oyewo, 2011; Osuoha & Fakutiju, 2017). As a consequence of its capacity to be a roadmap for other African countries seeking to enhance environmental quality, Nigeria has received special attention, hence, it has become imperative to investigate the impact of FD and urbanization on the environment degradation in Nigeria. This study in Nigeria aims to analyse the causal linkages between the environment and its variables and to assess the validity of the EKC.

The remainder of the study is as follows. Section 2 delves into an extensive literature review, encompassing theoretical review and empirical evidence. The 3rd section elaborates on the data and methodology employed in the research. The 4th section is dedicated to presenting and analysing the results, while the 5th Section concludes the study, emphasizing its policy implications.

2. LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Pollution Haven Hypothesis (PHH)

The impact of the bidirectional relationship between environment and trade is one of the major areas of debate. Talks on the link between environments intensified around the 1990's around which trade openness grew with the opportunity cost of worldwide distribution of industrial pollution. Hence, the importance of environmental economics as a subject area. The world leaders seek solutions to combat the reparation of increased trade on the environment (Zhang, 2023). There are two divergent views on trade and environment linked with opposing theoretical definitions with the same dynamics. First, the PHH and the PH.

Copeland and Taylor (1994) PHH concluded that firms that operate in heavily regulated economies like the USA, compete with those operating in less developed countries with lax environmental regulations. PHH predicts that NAFTA would end as a disaster to the environment of the lax regulated, while a job disaster for the highly regulated. The PHH asserts that commerce in products and foreign direct investment (FDI) are the main modes of transportation for the transfer of dirtier industries from industrialized to poor nations.

2.1.2 Environmental Governance Theory

Environmental governance requires making decisions to regulate the environment and nature's gifts. Nature plus the environment are public assets, and cannot be depleted when used by all. Sustainable development implies that the current generation leaves a habitable environment for future generations. As a result, the non-excludability and non-rivalrous character of such products need stringent control by public and private actors to prevent abuse or outright destruction (Ling et al., 2021).

2.2.3 Evolutionary Governance Theory (EGT)

According to the EGT, governance is an ongoing process of evolution. The EGT emphasizes coevolution by emphasizing the arrangements of institutions and actors, knowledge and power, and both official and unofficial rules. Each can be seen in light of its prior state, connections to other elements, and coevolution with other elements. Only through comprehending the coevolution of many knowledge forms (Van Assche et al., 2017; Beunen et al., 2022).

2.2 Empirical Review

Nasreen et al. (2017) conclude that the financial sector is crucial to mobilizing funds for commercial transactions, utilizing them, and keeping track of resources for economic growth. When the financial sector is completely developed, it encourages the efficient mobilization and distribution of resources, which is crucial for the economy to grow. Nigeria's financial industry aids in fostering economic growth. Therefore, it can be inferred that a successful financial sector will boost investment and encourage companies to employ green manufacturing techniques (Mesagan & Nwachukwu, 2018).

Researchers found that the emissions of carbon are going to be under control as and when the per capita threshold level is attained as the hypothesis of long run interaction between financial development and CO2 emissions cannot be proved. The financial developemebnt-CO2 emission nexus has been explored using cointegration method, ARDL, Granger causality, and panel data techniques, and many scholars have produced disparate results (see Cherni & Jouini, 2017; Ghazouani,2021; Salahodjaev et al., 2022; Shahbaz et al., 2013; Tamazian & Rao, 2010).

Furthermore, the allocation of loans to investments is affected by a country's level of financial development. Credits can enhance or deteriorate environmental quality. This is because financial institutions may consciously or accidentally reject credit facilities to enterprises with high carbon emissions, limiting funding to businesses with low carbon emissions. Consequently, various studies have demonstrated that the expansion of the financial sector may have a substantial influence on how successfully a country's environment is maintained through several channels (see Charfeddine & Khediri, 2016; Khémiri et al., 2024; Liu et al., 2024).

Human activities, mostly, carbon dioxide (CO_2) emissions increase, are categorized among the main factors contributing to climatic volatility in the recent decades, making it imperative to determine the factors that increase CO_2 emissions. Excess amounts of CO_2 emissions are harmful to the environment and air quality. Environmental policymakers are currently tackling these issues as a result of the greenhouse gas effect and global warming trends. Renewable energy resources pose less negative impact on the environment as compared to non-renewable -fossil fuel energy resources. Hence, the preference for renewable energy resources to the non-renewable. Consequently, renewable energy is crucial to environmental protection and is considered a viable option to enhance access to energy while mitigating climate change. Recently, studies have concentrated on this salient global issue-climate issue (see Asghar et al., 2023; Kumar & Rathore, 2023; Lal & You, 2024; Thomas et al., 2023)

Finally, Mesagan and Nwachukwu (2018), investigated the factors that impact the environment concentrating on the effect of FD. A time series analysis encompassing 1981- 2016 was used. The ARDL was used in the study with urbanization data, PCI, environment deterioration, energy use, intensity of trade, and capital invested. According to empirical findings, income, FD, energy consumption, and trade describe the environmental quality, whereas investment along with urbanization is insignificant in the model. There is no causal relationship between capital investment, financial progress, and the environment. Urbanization and income have a one-way effect on the environment. Furthermore, there is a two-directional correlation between energy usage and environmental damage. Financial sector operators must be careful to ensure the efficient allocation of credit to low-carbon enterprises.

3. METHODOLOGY

3.1 Theoretical Framework

The paper utilizes the EKC model – The Environmental Kuznets Curve (EKC) theory – which was similar to Kuznets (1995) hypothesis that inequality of income distribution and a country's economic growth are intrinsically related, and it has been generally found to reveal the connection between countries development and environmental degradation. By the same time environmental matters such as emission levels cannot be considered only with the carbon dioxide level. Nevertheless, but these two issues are not directly concerning the theoretical framework of EKC literature, they both are indirectly connected (Dogru et al., 2020). This implies that CO_2 emission – the explained variable –will be estimated as a function of financial development, urbanization and real GDP use as the independent variables in the estimation model.

3.2 Data and Sources

This study employed the time series secondary data spanning from 1986 to 2022, The variables adopted for the study include carbon Emissions (CO_2) measured in Metric tons per capita – see Chin et al. (2024), Erdogan et al. (2024), Nuţă et al. (2024) and Qamruzzaman et al. (2023) – urbanization (urb) measured as Urban population (% of the total population) and real GDP $(rgdp)$ all sourced from World Bank Indicators (WDI) and financial development (fd) measured as depth, access, and efficiency of financial institutions and markets sourced from international Monetary Fund (IMF).

3.3 Model Specification and Estimation Technique

Previous studies have focused on the financial development and carbon emission relationship, investigated using linear autoregressive distributed lagged (ARDL) model, succeeded by error correction (EC) techniques. Besides, econometric methods help in finding the role of long-term associations alongside the role of balancing short-term relationships, taking the linkage among financial development, urbanization and CO2 emissions symmetrically. Therefore, keeping in view that, they only give the limitations to the ideals and not the reality, hence, they are unable to achieve the asymmetry among variables (see Jaan et al., 2023; Moghaddam & Dehbashi, 2018; Shahrawat et al., 2015). Recently, empirical studies were carried out with the comparison of symmetry and asymmetry influence of FD on CO2, in a time series framework (see Ahmed et al., 2021; Ahmad et al., 2018; Ling et al., 2022; Omoke et al., 2020). Also, ample of studies expanded the symmetry ARDL of Pesaran et al. (1999) given birth to the asymmetry extension known as the nonlinear ARDL cointegration procedure (NARDL), which gives room for short- and long-run positive and negative shocks in desired explanatory variables.

The NARDL model provides a comprehensive understanding of the financial development and urbanization and CO2 emissions nexus has presented in the following symmetric long-run regression:

$$ln\,co2_t = \lambda_0 + \lambda_1\, ln\,urb_t + \lambda_2\, ln\, fd_t + \lambda_3\, ln\, rgdp_t + \varepsilon_t \quad (1)$$

where CO2 is carbon emissions, urb_t represents urbanisation, fd_t indicates financial development, and $rgdp_t$ depicts real GDP.

The above relationship displays the linear relationship between variables and the primary objective of this study is the exploration of the non-linear connection with CO2, URB, FD, and RGDP by using the nonlinear Autoregressive distribute lag (NARDL) has been introduced in by Shin and Greenwood-Nimmo (2014). The NARDL model has the following form of equation (1) is presented thus:

$$lnCO2_t = \sum_{j=1}^{p} \partial lnCO2_{t-j} + \sum_{j=0}^{q}\left(\pi_j^{+} lnx_{t-j}^{+} + \pi_j^{-} lnx_{t-j}^{-}\right) + \in_t \quad (2)$$

In equation (2) $lnx_t = \left[lnURB_t, lnFINDEV_t, lnRGDP_t\right]$ defined such that $lnx_t = Inx_0 + Inx_t^{+} + Inx_t^{-}$, ∂_j is the autoregressive parameter, π_j^{+} and π_j^{-} are the asymmetric distributed lag parameters, and $\in_t$ is the *iid* – independent and identical distributed – random variables process with zero mean and constant variance, $\sigma_{\in}^2$. x_t is decomposed on a zero mean-threshold, separating the shocks' effect of the X vectors. Following the work of Pesaran et al. (2001), equation (2) is reparametrised to the error correction model as follows:

$$\begin{aligned} ln\,co2_t &= \mu + \rho_{co2}\, ln\,co2_{t-1} + \rho_{urb}^{+}\, ln\,urb_{t-1}^{+} + \rho_{urb}^{-}\, ln\,urb_{t-1}^{-} + \rho_{fd}^{+}\, ln\, fd_{t-1}^{+} \rho_{fd}^{-}\, ln\, fd_{t-1}^{-} + \\ &\rho_{RGDP}^{+}\, ln\,rgdp_{t-1}^{+} + \rho_{Rrgdp}^{-}\, ln\,rgdp_{t-1}^{-} + \sum_{i=1}^{p-1}\gamma_i \Delta\, ln\,co2_{t-i} + \sum_{j=0}^{q-1}\left(\alpha_j^{+}\Delta\, ln\,urb_{t-j}^{+} + \alpha_j^{-}\Delta\, ln\,urb_{t-j}^{-}\right) + \quad (3) \\ &+ \sum_{j=0}^{r-1}\left(\delta_j^{+}\Delta\, ln\, fd_{t-j}^{+} + \delta_j^{-}\Delta\, ln\, fd_{t-j}^{-}\right) + \sum_{j=0}^{s-1}\left(\theta_j^{+}\Delta\, ln\,rgdp_{t-j}^{+} + \theta_j^{-}\Delta\, ln\,rgdp_{t-j}^{-}\right) + \varepsilon_t \end{aligned}$$

Where Δ is the first difference operator and ε_t is the error term. $urb_t^{+}, urb_t^{-}, fd_t^{+}, fd_t^{-}, rgdp_t^{+}$ *and* $rgdp_t^{-}$ are obtained through the decomposition of urb_t, fd_t *and* $rgdp_t$, respectively into positive and negative partial sums as follows:

$$urb_t^{+} = \sum_{j=1}^{t} \Delta urb_j^{+} = \sum_{j=1}^{t} \max\left(\Delta urb_j, 0\right);\ urb_t^{-} = \sum_{j=1}^{t} \Delta urb_j^{-} = \sum_{j=1}^{t} \min\left(\Delta urb_j, 0\right)$$

$$fd_t^{+} = \sum_{j=1}^{t} \Delta fd_j^{+} = \sum_{j=1}^{t} \max\left(\Delta fd_j, 0\right);\ fd_t^{-} = \sum_{j=1}^{t} \Delta fd_j^{-} = \sum_{j=1}^{t} \min\left(\Delta fd_j, 0\right) \quad (4)$$

$$rgdp_t^{+} = \sum_{j=1}^{t} \Delta rgdp_j^{+} = \sum_{j=1}^{t} \max\left(\Delta rgdp_j, 0\right);\ rgdp_t^{-} = \sum_{j=1}^{t} \Delta rgdp_j^{-} = \sum_{j=1}^{t} \min\left(\Delta rgdp_j, 0\right)$$

Finally, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests were employed to establish the order of integration for this study.

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

From Table 1, the carbon (CO2) emission measured in metric tons per capita has an average value of 0.694 metric tons per capita, less than the 4.69 metric tons per capita global carbon emission in 2021. This indicates that, on average, in Nigeria, the gases from the burning of fossil fuels and cement manufacture are pretty manageable over the period on the average, capturing aversion to global warming and lesser climatic change in the country. More so, the CO2 average value connotes that, on average, Nigeria is still within the Paris Agreement goal of limiting global warming to 1.5^{o}C of 2.3 metric tons per capita threshold. Meanwhile, the standard deviation of 0.128 metric tons per capita suggests that Nigeria is less exposed to fluctuations and volatility of carbon emissions. This indicates that the CO2 deviate from the mean value with almost 0.491 metric tons per capita during the study periods.

Table 1: Summary Statistics

	CO2	URB	FD	RGDP
Mean	0.6882	39.1571	49.6534	291.1470
Std. Dev.	0.1278	8.1009	11.6606	147.7833
Skewness	0.1851	0.2095	-0.3222	0.3950
Kurtosis	1.7129	1.8155	1.4808	1.5271
Jarque-Bera	2.8401	2.4994	4.3119	4.4231
Probability	0.2417	0.2866	0.1158	0.1095
Observations	38	38	38	38

Source: Authors' work

The financial development (FD) has a mean value of 49.6534, depicting that on average, during the periods under study, FD was 49.6534, while the fluctuation in 49.6534 recognising deviations from this average value measured via the standard deviation was 11.6606, suggesting that FD volatility was still manageable, as it clustered around the average value, implying that FD was less susceptible to change over time. Additionally, FD skewed negatively with a skewness of -0.322, depicting a left negative skewed of a long-left tail, while its peakedness was platykurtic (1.481 < 3), showing that FD extreme values characteristics are similar to that of the normal distribution, as the Jacque-Bera statistics' *p*-value of 0.116 established normal distribution of the series.

4.2 Stationary Tests

Precursory to the estimation of the NARDL model, the stationarity properties of the time-series were authenticated via the ADF and PP unit root techniques to establish their order of integration as presented in Table 2.

Table 2: Stationarity Tests

	Level		First Difference	
Variable	ADF	PP	ADF	PP
lco2	-3.0912	-2.9785	-7.2520***	-7.6669***
lurb	-3.4283*	-3.4283*	-8.7503***	11.7067***
lfd	-3.5788**	-3.2581*	-4.6482***	-6.7042***
lrgdp	-3.6036**	-1.5168	-3.8129**	-3.7043**

Source: Authors' work
Notes: * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

From Table 2, the stationarity test result using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) show that under the ADF, three variables – *lfd* , *lurb* and *lrgdp* – were stationary at the level whose *p*-values were less than 0.05 without differencing [I(0)], while *lco2* was stationary at first difference [I(1)] as the *p*-values are less than 0.05 significance level after differencing. Additionally, under the PP unit root tests, two (2) variables exhibited stationary at level [I(0)] –*lfd* and *lurb* – as their *p*-values were less than 0.05 without differencing, while the remaining two (2) – *lco2* and *lrgdp* – were stationary at first difference [(1(1)], with their *p*-value being less than 0.05 after the first differencing. This implies that the order of integration of the series is mixed, signifying and necessitating the use of the Nonlinear Autoregressive Distributed Lag (NARDL) as proposed by Shin et al. (2014), which allows mutually co-integrated series.

Table 3 presents the results of the long-run and the short-run estimates of the NARDL model. Starting with the short-run result, there is evidence that positive and negative URB shocks have a significant negative and positive association with CO2, respectively. This connotes that in the short run, increases in URB will lead to reduction in carbon emission (CO2), while the negative URB shock implies decline in Nigeria's carbon emission (CO2). These imply that the increase and decrease in urbanisation are significant factors influencing changes in carbon emissions in Nigeria. Furthermore, the short-run coefficient of positive and negative shocks in financial development is negative and positive, respectively. The estimates show that as financial development increases, it will lead to a decrease in carbon emission, while a decrease in financial development will lead to a decrease in Nigeria's carbon emission, hence increase and decrease in FD are significant factors influencing changes in carbon emission in Nigeria. Finally, in the short-run, the positive and negative shocks in real GDP exhibited a significant negative and positive nexus on carbon emission, respectively. The estimates show that as real GDP increases, it will lead to a decrease in carbon emissions, while a decrease in real GDP will lead to a decrease in Nigeria's carbon emissions. Thus, positive and negative shock in real GDP is a significant factor partially contributing to carbon emission in Nigeria.

Table 3: NARDL estimation results for financial development, urbanisation and carbon emission nexus in Nigeria.

	$lurb^{+}$	$lurb^{-}$	lfd^{+}	lfd^{-}	$lrgdp^{+}$	$lrgdp^{-}$
$\delta^{lurb^{+}}$	-0.1991** (0.0821)					
$\delta^{lurb^{-}}$		0.4432*** (0.0788)				
$\delta^{lfd^{+}}$			-0.2413* (0.1345)			
$\delta^{lfd^{-}}$				0.4237** (0.1855)		
$\delta^{lrgdp^{+}}$					-0.4547* (0.2254)	
$\delta^{lrgdp^{-}}$						3.1227** (1.2671)
$\lambda^{lurb^{+}}$	0.0541 (0.1753)					
$\lambda^{lurb^{-}}$		0.3250* (0.1794)				
$\lambda^{lfd^{+}}$			0.7056** (0.2829)			
$\lambda^{lfd^{-}}$				0.5081 (0.3176)		
$\lambda^{lrgdp^{+}}$					0.7688** (0.3187)	
$\lambda^{lrgdp^{-}}$						3.4326* (1.8416)
γ^{ect}	-0.5733*** (0.0064)					

Source: Authors' work

Note: The values in parentheses are the standard errors. The $\delta s'$ are for the short run while the $\lambda s'$ are for the long run. ***, ** & * imply significance at the 1%, 5% and 10% levels, respectively

The nonlinear ARDL cointegration test is based on the joint F-statistics for long-run associations (see Shin et al.2014). As exhibited from the table 4, the F-statistic of 7.322 is greater than the upper critical bound [I(1)] –3.28 – at 5% significance level, thereby showing that cointegration among the variables exists, which helps to interpret long-run coefficient estimates.

Table 4: Post-Estimation Diagnostic Tests

Diagnostic Tests
$R^2 = 0.8864$ $\bar{R}^2 = 0.8126$ $DW = 2.5747$
$X^2_{LM} = 4.4768[0.1144]$ $X^2_{BGP} = 17.8280[0.5987]$ $X^2_{JB} = 1.1241[0.5700]$ $X^2_{RS} = 0.1059[0.1751]$
$F-statistic = 10.5988[0.0000]$ STABILITY=CUSUMSQ
NARDL bound test

$F - statistic = 7.3219\left[I\left(0\right) = 2.27, I\left(1\right) = 3.28 \,@\, 5\% \right]$

Source: Authors' Own work

Notes: DW: Durbin Watson statistics. statistics ***,** and * indicate significance at 1%,5% and 10%, respectively. $X^2_{LM}, X^2_{BGP}, X^2_{RS}, X^2_{JB}$ represent LM test for serial correlation, Breusch-Pagan Godfrey test for heteroscedasticity, Ramsey rest test for model specification and Jarque-Bera normality test, respectively. I(0) and I(1) represent lower and upper bound, respectively. $[\ ]$ indicate respective probability values.

The long run dynamic exhibited that decrease in urbanisation has a significant positive association with CO2 emissions in Nigeria, implying that decreases in urbanisation lead to decreased carbon emissions, hence, a decrease in urbanisation is a significant factor influencing fluctuations in carbon emission in Nigeria. Additionally, increase in financial development is significantly positive, declaring that as financial development increases, it will lead to an increase in carbon emissions. Finally, the coefficient of increase and decrease in real GDP is positive, as the estimates show that as real GDP increases (decreases), it will lead to a rise (fall) in carbon emissions. This connotes that positive and negative shocks in real GDP are a significant factor influencing fluctuations in carbon emission in Nigeria.

The impressive aspect in the long-run dynamics is a revelation of dissimilar impact of tight and loose financial development, urbanisation and real GDP on carbon (CO2) emission. Likewise, CO2 response to decrease in real GDP is significantly higher than to increase in real GDP. That is, low productivity through easing or decreasing real GDP by a certain magnitude causes a higher increase in carbon emission than tightening or increasing real GDP. Meanwhile, discouraging rural-urban migration has a higher impact than encouraging, as revealed via the 0.33 per cent significant contribution of URB Negative shock on CO2 against the 0.05 per cent insignificant impact of the URB positive shock on CO2 (see Table 3). On the contrary, it was the positive shock of financial development that had the highest significant impact – in magnitude – on CO2, as it exerted a whopping 0.706 per cent impact on CO2 as against the insignificant 0.508 per cent accounted by negative shock.

Also of note, the non-significance of the URB positive shock and FD negative shock implies that the percentage increase in urban population due to rural migration is not practical to CO2 in the long run, as it will increase environmental pollution and degradation. This may also be as a result of the lag period involved in making migration decisions based on prevailing economic phenomena. More so, the speed of adjustment coefficient is negative and statistically significant as required with -0.573 indicating that about 57.33% of the short-run deviations from the long-run equilibrium are being adjusted annually. Alternatively, the adjustment is calculated by taking the inverse of the absolute value of the ECT to show how long it takes for the deviations from equilibrium to return to equilibrium (Pao & Tsai, 2010). Therefore, the adjusted speed for this study is 1.7 years (i.e., $1/0.5733$), which implies that it would take about 1 year and 5 months for short-run deviations from the long-run to be corrected.

Some post-estimation diagnostics tests were conducted (see Table 4) to establish that the estimated model is free from multicollinearity, autocorrelation, serial correlation, and heteroscedasticity, as they were all confirmed absent. In addition, the normality and linearity of the residuals were diagnosed with the Jarque-Bera test and the Ramsey Reset test, confirming the normality and linearity of the residuals.

The Wald test output in Table 5 shows a significant short-run asymmetric nexus among the variables at 1%, 5% and 10% for urbanisation (URB), financial development (FD) and real GDP (RGDP). Meanwhile, in the long run, other variables exerted long-run asymmetric except URB with long-run symmetric association.

Table 5: Results of the asymmetry Wald test

Variables	$X^2 Chi-Square$	$[prob]$	**Is there asymmetry?**
Long run			
lurb	0.2249	0.6353	No
lfd	12.8386***	0.0003	Yes
lrgdp	11.4419***	0.0081	Yes
Short run			
lurb	9.2867***	0.0023	Yes
lfd	27.6336***	0.0000	Yes
lrgdp	7.4505***	0.0063	Yes

Source: Authors' compilation

Note: ***, ** and * symbolizes the rejection of the hypothesis at a 0.01%, 0.05% and 0.10% level of significance.

Empirically, in comparison with existing literature, there is a corroboration with studies such as Jiang and Ma (2019) and Nasreen et al. (2017) which suggest that financial development can have both positive and negative effects on CO2 emissions. The nuanced relationship observed in the short run echoes the idea that the impact of financial development on the environment can vary based on different circumstances (Dasgupta et al., 2001). Additionally, the long-run positive association between urbanization and carbon emissions is consistent with findings by Omoke et al. (2020). On the other hand, Liu and Liu (2021) conclude that financial development does not impact on carbon emissions or the environment. The empirical findings of this study contribute to the growing literature on the asymmetric impact of financial development and urbanization on CO2 emissions. The results emphasize the need for a nuanced understanding of these relationships, considering both short-run and long-run dynamics, as well as the asymmetry in the impact of positive and negative shocks. The findings align with and extend the insights provided by previous research (see Akca, 2021; Ahmad et al., 2022; Hashmi et al., 2021; Kibria et al., 2021; Rjoub et a., 2021; Rufai et al., 2022; Talib et al. (2022), shedding light on the complexity of the interactions between financial development, urbanization, and environmental outcomes in the context of Nigeria.

The Wald test results, however, show that there exist short-run and long-run asymmetry in these relationships, which provide evidence for the same non-linear and asymmetric nature of the relationship between financial development, urbanization and CO2 emissions in different countries as found by scholars (Lawal, 2023; Moghadam & Dehbashi, 2018; Salahuddin & Gow, 2019; Xu et al., 2018).

Theoretically, the finding is in tandem with the Environmental Kuznets Curve Hypothesis as identified in the study. Grossman and Krueger (1991), proposed an inverted U-shaped link between growth and CO2 emissions known as the EKC. The focus is on the repercussions of ongoing economic expansion as being capable of causing greater harm to the earth's ecosystem. Furthermore, if increases in income and wealth plant the seed for the amelioration of environmental problems, the results will be essential in creating acceptable development plans for less developed nations. The primary principle of the EKC forms that income level rise leads to an increase in the emissions of CO2; however, in the initial stages of economic growth.

However, as development progresses, the reverse influence of wealth on pollution turns positive. In other words, an increase in wealth is caused by a decrease in CO2 emissions, resulting in an inverted U- curve. Countries with strong financial development can invest in cleaner energy sources. It is significant because an inverted U-shaped EKC will prevent environment breakdown at a particular time during growth in economic terms, and the quality of the environment will improve as economies continue to rise. To put it differently, economic activities frequently cause environmental degradation, and at the start of economic expansion, individuals care less or are unable to maintain the environment. However, when people's income grows, they tend to increase their expenditure on pollution-reduction efforts. Consumers increasingly prefer to buy hybrid automobiles or new houses with modern heating systems over dwellings that utilize filthy fuels such as coal (Brown & Shaw, 1999).

According to the EKC model, during the early stages of expansion, pollution levels climb until they reach the previously indicated positive turning point, after which economies begin to see a decline in pollution.

5. CONCLUSION AND POLICY IMPLICATIONS

This study has investigated financial development, urbanization and carbon emission in Nigeria using the NARDL technique over the period 1986-2022. The evidence has indicated the existence of short- and long-run asymmetric for the variables except urbanization, which depicted a symmetric association in the long-run with carbon emission. Consistent with the findings, this study offers some key policy implications. The study suggests that financial development has a positive link to long-term CO2 emissions reduction. The government should consider this when formulating policies to reduce emissions. GDP growth can mitigate CO2 emissions, so Nigeria should increase its GDP. More so, the financial system should empower businesses to adopt modern, safer, and environmentally sustainable technologies, as adopted by Sterling Bank Plc. The government should also enhance its financial systems to increase funds for environmental initiatives, improve technical advancements, and encourage research and development to lower environmental problems. The study also suggests stronger energy adoption, particularly in metropolitan areas, which are hubs of economic activity that generate massive greenhouse emissions. Future research should compare these findings across diverse regions in Africa.

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