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ASSESSING THE POLLUTION HAVEN HYPOTHESIS IN NIGERIA: EVIDENCE FROM ARDL ANALYSIS OF CO_2 EMISSIONS AND ECONOMIC INDICATORS

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Abstract

This study investigated the validation of the pollution haven hypothesis (PHH) in Nigeria. The study used CO_2 emissions as the key indicator of environmental pollution and considered relevant explanatory variables such as foreign direct investments, economic growth, financial development, and population growth to achieve its objective. Covering the time series data from 1990 to 2023, the Autoregressive Distributed Lag (ARDL) model was applied. The findings revealed a long-run cointegration between the considered variables, and the ARDL results validate the PHH in Nigeria. Foreign direct investment inflows contribute to the rising levels of CO_2 emissions in Nigeria. In addition, financial development and per capita GDP reduce the levels of CO_2 emissions, [redacted] while population growth causes a rise in environmental degradation in the country. Based on the aforementioned findings, this study recommends that the government, policy-makers, industries, and interested parties of the country should apply and execute policies, laws, and regulations that will deter or punish polluting foreign multinational companies and other investments and

Keywords: pollution haven hypothesis, environment, foreign direct investment, Nigeria, population.

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encourage clean ones; since green finance is gaining popularity but not well established in most African countries, Nigeria inclusive, green financing systems should be initiated, sustained and implemented; establish preferential trading policies that will promote addition of value through clean technology; and practice carbon capture, usage, and storage for the country's environmental safety.

Introduction

Economic globalization has intensified the pursuit of sustainable development, as escalating CO_2 emissions, a major contributor to global warming, pose significant threats to health, food security, climate stability, and overall human well-being. While both developed and developing nations face environmental challenges, the adverse effects of carbon emissions are particularly severe in developing countries, where rapid industrialization, population growth, and urbanization often lead to heightened environmental degradation (Ogunjobi, et al., 2025; Wu & Wang 2023). A central tenet in the discourse on environmental economics is the Pollution Haven Hypothesis (PHH). The PHH suggests that multinational companies from industrialized nations may relocate pollution-intensive production to countries with less stringent environmental regulations. In doing so, these countries attract foreign direct investment (FDI) while shouldering the ecological costs associated with increased industrial activity. On the other hand, some scholars argue that FDI can introduce advanced, cleaner technologies, a phenomenon sometimes referred to as the "Pollution Halo" effect (Boamah, et al. 2023).

Nigeria provides a pertinent context for examining these dynamics. As Africa's largest economy, Nigeria has experienced substantial FDI inflows, rapid economic growth, and significant urban expansion. However, these positive economic developments are accompanied by rising CO_2 emissions. Cities like Lagos, where industrial facilities are often located near densely populated areas, vividly illustrate the conflict between economic progress and environmental health (Ayadi, 2020). Despite various initiatives, ranging from international agreements such as the Paris Agreement to domestic policy reforms, efforts to curb carbon emissions have yet to yield the desired outcomes.

Even though the prior studies have recurrently investigated EKC and PHH, a few insufficiencies in the prevailing literature have been identified. First, the research

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on the impact of foreign direct investment, economic growth, and population growth on CO_2 emissions using the ARDL model is relatively uncommon in the Nigerian literature. Second, the validity of the Pollution Haven and Pollution Halo hypotheses has not been fully and simultaneously examined for Nigeria. To pledge these shortages, the study examines the validity of Pollution Haven and Pollution Halo hypotheses for Nigeria from 1990 to 2023 using the ARDL model. Furthermore, this study contributes to the existing literature in the following ways. First, this study uses the ARDL approach to examine the relationship between the variables. Compared to other estimation procedures, the ARDL model is more functional in integrating variables to order zero, one, or mixed orders one and zero. Furthermore, the ARDL estimation process covenants with the potential endogeneity problem of the concerned variables and is formed to be efficient in the case of small samples. Moreover, the study investigates the PHH hypothesis in the context of FDI. In addition, unlike other studies that concentrated on the relationship between FDI and CO_2 emissions in Nigeria, this study incorporates economic growth and population growth in the function of CO_2 emissions along with FDI inflow and financial development. Finally, to the best of the authors' knowledge, limited studies have been performed in environmental economics in the context of Nigeria. Hence, the study contributes to the existing literature and further enhances the international debate on environmental degradation and its impact. The findings of this study hold significant policy implications. If the PHH is validated, it would suggest the need for stricter environmental regulations and the promotion of green financing mechanisms to deter environmentally harmful investments and encourage the adoption of cleaner technologies. Ultimately, this research contributes to the broader international debate on environmental degradation, providing insights that are valuable not only for Nigeria but also for other emerging economies facing similar challenges.

The remainder of this paper is organized as follows: the next section reviews relevant literature, followed by a description of the data, methodology, and the ARDL model employed. Subsequent sections present the results and discussion, and the paper concludes with policy recommendations aimed at fostering sustainable development in Nigeria.

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Literature Review

Pollution Haven (PHVH) and Halo (PHLH) Hypotheses

The pollution Haven Hypothesis (PHH) was first propounded by Copeland and Taylor (1994) in the context of North-South trade under North American Free Trade Agreement (NAFTA), the first paper that connected the environmental regulation stringency and trade patterns with the level of pollution in a country. Under NAFTA the firms operating in highly regulated countries like Canada and USA came in direct competition with the firms operating in poor countries that have relatively lax environmental standards like Mexico. Copeland and Taylor (1994) predicted that NAFTA would become an environmental disaster for Mexico and job disaster for the USA. They further submitted that under the trade liberalization, the firms that produce dirty goods would move from rich countries that have stringent environmental regulations to those developing countries that have comparatively weak environmental regulations. Therefore, in open and liberalized trade the developing countries would become pollution haven for the dirty industries of the advanced countries. The PHH predicted an environmental disaster in these developing countries that had relatively weak environmental regulations.

The pollution haven hypothesis postulates that, as countries develop, they adopt stricter environmental regulations than countries in the developing stage. Consequently, this negatively affects the existing comparative advantage patterns. As a result, the polluting industries relocate their facilities and activities from developed to developing countries, turning the latter into pollution havens (Boumah et al. 2023). On the other hand, the pollution halo hypothesis asserts that international corporations convey their greener technologies to developing countries through FDI, Green innovations, such as those that reduce pollution or use renewable energy sources and highly energy-efficient ones, lessen the need for traditional energy sources (Boumah et al. 2023).

As captured by the PHH, the movement of the dirty industries from advanced to developing countries takes place through the trade of goods and foreign direct investment (FDI). This phenomenon is induced by the comparative cost advantage enjoyed by the developing countries due to less stringent pollution control measures. The developed countries tend to specialize and export clean goods while the developing countries tend to specialize and export polluted goods.

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Resultantly, the developing countries are becoming the pollution haven for the dirty industries of the advanced countries. Since the introduction of these hypotheses, numerous studies have been conducted to determine their viability, some involving two or more countries, while others were country specific. Despite trending areas of research, the conclusions drawn concerning these hypotheses have been contradictory (Ogunjobi, et al., 2025).

Empirical Literature Review

There is a plethora of research studies that have focused on economic growth to explain environmental quality under different settings such as different samples, different time periods, and different control variables. These studies produce diverse outcomes as they rely on different environmental indicators and alternative econometric methods. Many authors (Kilinc-Ata et al., 2025; Olaoye et al., 2025; Ogunjobi et al. 2025; Ali et al. 2025; Jama & Abdi, 2025; Habimana Simbi et al., 2025; Zhao & Su, 2023; Huang et al. 2023; Saussay & Zugravu-Soilita, 2023; Raihan, 2023; Wu & Wang, 2023; Ozkan et al. 2023; Abbasi et al. 2023; Apergis et al. 2023; Aminu et al. 2023; Ozturk et al. 2023; Bekun et al. 2022; Firoj et al. 2022) support the authenticity of the PHH hypothesis. However, some studies do not confirm the presence of PHH in different settings (Pat-natson et al., 2025; Chishty et al., 2025; Jeetoo & Chinyanga, 2023; Boamah, et al. 2023; Mirhoseyni et al. 2023; Leonardoa et al. 2023; Tchouto 2023; Chen, 2021).

The relationship among Nigeria's CO_2 emissions, foreign direct investment inflows, and economic growth was examined by Ogunjobi et al. (2025) by adopting the VECM-based Granger causality technique and the results showed a feedback relationship between FDI inflows and CO2 emissions as well as a unidirectional causal relationship from economic growth to CO2 emissions. Olaoye et al., (2025) investigated how financial inclusion affects the connection between energy use and environmental quality in 20 low-income sub-Saharan African nations by employing cross-sectionally augmented autoregressive distributed lag (CS-ARDL) technique, and they discovered that energy use significantly increases carbon emissions over the short- and long-terms, while financial inclusion has a positive yet statistically insignificant short-term effect on environmental quality, a positive correlation was also found between carbon emissions, real GDP and gross capital investment. In a similar study conducted by Kilinc-Ata et al. (2025), the impacts of

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economic policy uncertainty on the load capacity factor was examined by employing the Fourier Autoregressive Distributed Lag method to investigate the long- and short-term effects of energy intensity and economic growth and the findings show that whereas economic policy uncertainty temporarily improves environmental quality in China, it only has a long-term detrimental effect on environmental quality in the United States. While examining the role of per capita income on environmental outcomes incorporating geopolitical risks as a critical determinant, Ali et al. (2025) employed autoregressive distributed lag (ARDL) estimation technique and their findings confirm the inverted U-shaped EKC hypothesis for Canada, indicating that economic growth initially exacerbates carbon emissions before leading to environmental improvements at higher income levels; geopolitical risks are found to positively contribute to CO_2 emissions.

In a related development, Habimana Simbi et al., (2025) examined the long-term association among CO_2 emissions, economic growth, and different socio-economic factors in 36 African countries from 1990 to 2020 by employing the Pooled Mean Group (PMG) estimator with Autoregressive Distributed Lag (ARDL) model, along with U-test and Dumitrescu and Hurlin causality analyses, and the study reveals long-term nexus amongst CO_2 emissions and economic growth, trade openness, renewable energy consumption, urbanization, and population dynamics, supporting the Environmental Kuznets Curve (EKC) hypothesis. Zhao & Su (2023) support the PHH by examining the relationship between air pollution and outward foreign direct investment in China using the bootstrap rolling-window full- and subsample Granger causality test and the results revealed that air pollution negatively affect OFDI in 2016, while this influence became positive at the end of 2019. Jama and Abdi (2025) examined the causal links between energy consumption, FDI, urbanization, and carbon emissions in Somalia using ARDL bounds test. The outcomes revealed that in the long run, energy consumption, FDI, and urbanization have a positive effect on CO2 emissions in Somalia. Huang et al. (2023) investigated the impact of economic policy uncertainty, GDP per capita, renewable energy consumption, and foreign direct investment on environmental sustainability from the perspectives of the pollution halo/haven hypotheses by employing panel corrected standard errors (PCSE) and generalized

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least squares (GLS). The results reveal that EPU, GDP per capita, REC, and FDI significantly impact GHG emissions, contributing to climate change.

In another study from China, Wu & Wang (2023) employed systematic GMM model to analyze data from 30 regions and explores their impact studies on air pollution from the perspectives of environmental regulation and foreign direct investment. They conclude that, foreign direct investment aggravates the environmental pollution problem in China, and the overall status quo is consistent with the pollution haven hypothesis, which shows an inverted U-shaped curve between FDI and air pollution. Ozkan et al. (2023) investigated the validity of the environmental Kuznets curve (EKC), pollution haven, and pollution halo hypotheses by applying the dynamic autoregressive distributed lag simulations and the study found that foreign direct investment has negative effects on environmental quality in China, implying that the case of China exemplifies the pollution haven hypothesis and not the pollution halo hypothesis.

There are some studies that do not confirm the presence of PHH in different settings. For example, Chishty et al. (2025) analysed how FDI, financial development and green technological innovation influence environmental quality in BRICS Economies using Pooled Mean Group (PMG) and Autoregressive Distributed Lag (ARDL) model. They found a significant, negative long-term association between broad money, FDI, green technological innovation, and CO2 emissions, while domestic credit to the private sector shows a positive and significant relationship with carbon emissions. Pat-natson et al. (2025) used dynamic fixed effect model to examine the impact of green financing on Nigeria's environmental sustainability by assessing the effects of carbon finance, green credit, and green securities. the findings indicate that while carbon financing and green credit negatively affect carbon emissions, electricity production using hydroelectric sources serves as a positive predictor. Jeetoo & Chinyanga (2023) assessed the environment Kuznets curve (EKC) and pollution haven (PH) hypotheses in Sub-Saharan Africa (SSA) using spatial panel econometric analysis of the spatial Durbin model (SDM) by employing a balanced panel of 35 SSA nations from 2002. The findings confirm the EKC theory about the depletion of natural resources in SSA. The EKC theory, however, does not apply to CO2 emissions, supporting the PH theory.

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Abbasi et al. (2023) examined the pollution haven, pollution halo, and environmental Kuznets curve for a number of Asian countries during the period of 1985 to 2020 using Pooled mean group (PMG). The results suggest that urbanization, gross domestic product per capita, energy consumption, and foreign direct investment inflow have positive effects, while gross domestic product square, foreign direct investment square, and tourism have negative effects on emissions of carbon dioxide. Apergis et al. (2023) analyzed the impact of FDI flows on carbon emissions in Brazil, Russia, India, China, and South Africa (BRICS) between 1993 and 2012 using bilateral FDI flows from eleven OECD countries. Their results confirm that FDI flows to BRICS countries from Denmark and the UK increase carbon emissions in BRICS countries, confirming the pollution haven hypothesis. On the other hand, FDI that flows from France, Germany, and Italy reduced carbon emissions in the BRICS countries, confirming the pollution halo effect. FDI flows from Austria, Finland, Japan, Netherlands, Portugal, and Switzerland have no significant impact on carbon emissions in BRICS countries. Boamah, et al. (2023) analyzed how foreign direct investment and other variables influence CO2 emissions levels and tested the validity of the pollution haven and halo hypotheses by employing data from 41 African countries from 2005 to 2019. By applying the pooled least squares, fixed and random effects models, and the generalized method of moments, the findings revealed that the pollution haven and halo hypotheses do not hold, foreign direct investment inflows contribute to the rising and falling levels of CO_2 emissions, and as well, the financial structure and per capita GDP increase the African countries' CO_2 emissions, while trade openness causes a reduction. Bekun et al. (2022) explored the interaction between the that FDI inflow, renewable energy, and induced environmental degradation from 1970 to 2016 in Turkey by employing Autoregressive distributed lag and dynamic ordinary least squares methodology. Empirical results validate the pollution haven hypothesis (PHH) in the long run for the case of Turkey.

Raihan (2023) investigated the effects of foreign direct investment on sustainable development in Bangladesh using annual data between 1990 and 2019, and investigated the evidence of the Environmental Kuznets Curve and the Pollution Haven Hypothesis in Bangladesh by utilizing autoregressive distributed lag method. He concludes that the country has an inverted U-shaped Environmental Kuznets Curve and the adverse impact of foreign direct investment on the

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environment confirmed the validity of the Pollution Haven Hypothesis in Bangladesh. Mirhoseyni et al. (2023) examined the pollution shelter hypothesis in Iran using an econometric model of Auto Regressive Distributed Lag (ARDL). The results indicate that an increase in CO_2 emissions per capita increases Foreign Direct Investment (FDI) flows in Iran. The relationship between economic openness and the foreign direct investment flow was confirmed by the positive and significant coefficient of the Trade Freedom index in Iran. Finally, it was found that there is a positive relationship between the population growth rate and foreign investment flow in Iran. Firoj et al. (2022) investigated the pollution haven hypothesis (PHH) validation and existence of the environmental Kuznets curve (EKC) hypothesis in Bangladesh covering the time series data from 1986 to 2018, the autoregressive distributed lag (ARDL) approach was applied. The findings revealed a long-run cointegration between the considered variables, and the ARDL results cannot validate the PHH in Bangladesh. These results contribute to the existing literature by concentrating on the EKC hypothesis for financial development purposes. Furthermore, it was found that urbanization, gross fixed capital formation and trade openness positively influence CO2 emissions, while energy use reduces CO2 emissions.

Data and Methodology

Data

This study intends to assess the validity of pollution Haven hypothesis in Nigeria using annual data from 1990-2023. This is because, data on CO2 emissions in Nigeria started from 1990. Specifically, data on CO2 emissions, foreign direct investment inflows (FDI), real gross domestic products (RGDP) measured in constant 2015 US$, proxied for economic growth, domestic credit to private sector (% of GDP) proxied for financial development (FD), and population growth are sourced from World Development Indicators (WDI) of the world bank.

Table 1. Description of the Variables

Variables	Code	Description	Source
CO_2 Emissions (Thousand kilo Tonnes)	CO_2	This is measured by the total emission of carbon dioxide stemming from the burning of fossil fuels, they include carbon dioxide produced from consumption of solid, liquid, and gas fuels and gas flaring	WDI, WB

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Variables	Code	Description	Source
Foreign Direct Investment inflows (% of GDP),	FDI	Foreign direct investment shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors divided by GDP	WDI, WB
Financial Development	FD	This is the Domestic credit to private sector as a percentage of GDP.	WDI, WB
Population Growth constant 2015 US$)	POPG	Total population counts all residents regardless of legal status or citizenship	WDI, WB
GDP per capita (constant 2015 US$)	GDPP	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes, minus subsidies not included in the value of the products. Data are in constant 2015 U.S. dollars	WDI, WB

Source: Authors' compilation

Model Specification

Following the existing literature, the study adapted the model used by Firoj et al. (2022). While Firoj et al. (2022) used the variables of carbon dioxide emissions (CO_2), financial development represented by domestic credit supply (DCP), foreign direct investment (FDI), trade openness (TO), gross fixed capital formation (GCF), energy consumption (ENG), and urbanization (URB).; this study differed by using carbon dioxide emissions (CO_2), financial development (FD), foreign direct investment inflows (FDI), and population growth instead of urbanization to better explain the existence or otherwise of PHH. The functional and baseline models are presented below:

CO_2 =f(FDI, GDPP, FD, POPG).....(1)

For the smoothness of data and to avoid the violent fluctuation caused by the change of data, the variables are transformed into natural logarithm form. Thus, the linear model is presented in the following form:

$$LCO_2 = \beta_0 + \beta_1 LFDI_t + \beta_2 LGDPP_t + \beta_3 FD_t + \beta_4 LPOPG_t + \varepsilon_t \text{.....(2)}$$

where LCO_2 is the logarithm of carbon dioxide emissions proxied for environmental quality, LFDI is the logarithm of Foreign direct investment, LGDPP is the logarithm of GDP per capita proxied for economic growth, FD is the financial development (%of GDP), LPOPG is the logarithm of population growth, β_o is the

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constant intercept, β_1- β_4 are the coefficients of explanatory variables to be estimated, and ε is the error term which is assumed to be normally distributed.

Method of Data Analysis

Unit root test

This study employed both the conventional unit root tests of augmented Dickey-Fuller (ADF) unit root test with structural breaks to test the stationarity status of the variables. However, the conventional unit root tests are said to be biased in the presence of structural breaks as posited by Inuwa et al. (2022). Therefore, to avoid this problem, the study employed the Lee - Strazicich (2003) LM unit root test with two breaks because of its better size and higher power in addition to identifying structural breaks more accurately than Zivot and Andrews (1992), and Lumsdaine and Papell (1997) Inuwa et al. (2022).

ARDL estimation with cointegrating bounds

Some important scholarly arguments have made the Autoregressive Distributed Lag (ARDL) approach more popular in recent years. For instance, it is applicable irrespective of either the regressors are I(0), I(1), or fractionally integrated when other methods of cointegration like Johansen and Juselius impose an antagonistic assumption that all the regressors in the model have to be integrated of the same order (Zhang et al. 2024). Another good side of the ARDL method is that it investigates the complex short term and long-term relationships among the variables under examination, enhance effective accuracy, and offer potential solutions beyond the complexities encountered with other cointegration approaches (Udeagha & Ngepah, 2022).

The order of integration for all of the variables were checked through the ADF, PP and Lee- Strazicich unit root tests, and to test for cointegration among the variables, where F-statistics will be computed with the critical values provided by Narayan (2005), which appropriate for small sample size to test for the existence of a cointegrating relationship among the variables. The null hypothesis;

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$, that there is no cointegration among the variables.

H_1: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 \neq 0$, that there is cointegration among the variables.

Equation (3) can be specified in the form of ARDL bound equation with optimal lag:

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$$\Delta LCO2_t = \alpha_0 + \alpha_1 LCO2_{t-1} + \alpha_2 LFDI_{t-1} + \alpha_3 LGDPP_{t-1} + \alpha_4 LFD_{t-1} + \alpha_5 LPOPG_{t-1} + \sum_{I=1}^{q} \beta_1 \Delta LCO2_{t-1}$$

$$+ \sum_{I=0}^{K_2} \beta_2 \Delta LFDI_{t-1} + \sum_{I=0}^{K_3} \beta_3 \Delta LGDPP_{t-1} + \sum_{I=0}^{K_4} \beta_4 \Delta LFD_{t-1} + \sum_{I=0}^{K_4} \beta_4 \Delta LPOPG_{t-1} + \mu_t \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where: β_i is the short-term coefficients, while long-term coefficients are represented by α_i with $I = 1\ldots$ n. CO_{2t} is the dependent variable, with optimal lag q; while FDI_t, $GDPP_t$, FDt, and $LPOPG_t$ are used as independent variables, with optimal lags as k_i.

The short-run equation estimates The Error Correction Term (ECT), with the speed of adjustment of the model to long-run equilibrium convergence. Equation 3 is a combination of short and long-run equations. The long- run component is expressed as:

$$\Delta LCO2_t = \alpha_0 + \alpha_1 LCO2_{t-1} + \alpha_2 LFDI_{t-1} + \alpha_3 LGDPP_{t-1} + \alpha_4 LFD_{t-1} + \alpha_5 LPOPG_{t-1} + \mu_t \ldots\ldots(4)$$

The short-run component of Equation 4 is expressed as:

$$\Delta LCO2_t = \alpha_0 + \sum_{I=1}^{q} \beta_1 \Delta LCO2_{t-1} + \sum_{I=0}^{K_2} \beta_2 \Delta LFDI_{t-1} + \sum_{I=0}^{K_3} \beta_3 \Delta LGDPP_{t-1} + \sum_{I=0}^{K_4} \beta_4 \Delta LFD_{t-1}$$

$$+ \sum_{I=0}^{K_4} \beta_5 \Delta LPOPG_{t-1} + \lambda ECT + \mu_t \ldots\ldots\ldots\ldots\ldots\

wise correlation matrix is used to measure the presence or otherwise of multicollinearity in the model. The results revealed the strength of correlation between a pair of variables. The higher coefficient of correlation ($r \geq 0.8$) shows severe multicollinearity among the variables. The results of the pair-wise correlation matrix statistics in Table 2 indicates that explanatory variables are weakly correlated.

Table 2. **Descriptive Statistics and Correlation Matrix**

Variables	CO2	FDI	GDPP	FD	POPG
Mean	11.46261	1.654596	7.568119	10.16841	18.76291
Median	11.46516	1.523782	7.575648	8.909485	18.76065
Maximum	11.69144	5.790847	7.893406	19.62560	19.15462
Minimum	11.19504	0.183822	7.264739	4.957522	18.37164
Std. Dev.	0.127342	1.207931	0.236576	3.546446	0.240135
Skewness	-0.130968	1.827580	0.010242	0.908566	0.012269
Kurtosis	2.251695	6.724000	1.347495	3.522255	1.765240
CO2	1.000000				
FDI	-0.557885	1.000000			
GDPP	-0.184035	-0.072101	1.000000		
FD	0.180864	-0.025121	0.076993	1.000000	
POPG	0.691658	-0.401029	-0.058359	0.693182	1.000000

Source: Author's Compilation using Eviews 10

This study applied ADF unit root test to examine the stationarity properties of the variables as presented in Table 3.

Table 3. Unit Root Tests Results

	Level	First Difference	
Variables	t-stat	Variables	t-stat.
LCO2	-2.942633	LCO2	-5.549099***
FDI	-4.001297***	FDI	---
LGDPP	-2.314301	LGDPP	-3.372615***
FD	-3.598426**	LFD	-5.589161***
LPOPG	-4.745934***	LPOPG	- - -

***, ** and * show significance at 1%, 5% and 10% levels respectively

Source: Author's Compilation using Eviews 10.

From the ADF test results in table 3, LFD and LPOPG are stationary at level I(0) while CO2, LGDPP and FD are stationary at first difference I(1). Therefore all the

variables are combination of both I(0) and I(1). Thus, the variables are qualified to run for NARDL approach to co-integration.

Table 4. Unit Root Tests Results with Structural Breaks

Level			First Difference		
Variables	t-Stat	SBa	Variables	t- Stat	SBb
LCO2	-6.198956	1996 2002	LCO2	-6.444417***	2001 2011
FDI	-5.272353	1998 2003	FDI	-7.483170***	1991 1996
LGDPP	-5.259164	1994 2006	LGDPP	-7.109939***	1990 2000
FD	-5.289314	1992 2010	FD	-6.820017**	2009 2014
LPOPG	-14.62000***	1993 2007	LPOPG	- - -	

***, ** and * show significance at 1%, 5% and 10% levels respectively

Source: Author's Computation.

The study employed the Lee Strazicich LM unit root test as presented in Table 4. The test has the capacity to account for two breaks points i.e., innovative and additive outliers, with additive outlier as most preferable because it deals with sudden changes in the mean of the variables as posited by Inuwa et al. (2022). The findings are in conformity with the outcome obtained from the previous test (ADF) that the variables are combination of both I(0) and I(1).

Lag Length for F- Bound Cointegration Test

The result of the optimal lag length is presented in the table below.

Table 5. Lag Length for F- Bound Cointegration Test

Lag	LogL	LR	FPE	AIC	SC	HQ
0	10.52181	NA	0.036480	-0.480157	-0.233311	-0.418076
1	54.31859	64.74307*	0.000887	-4.201616	-3.905401	-4.127119
2	56.13781	2.531091	0.000764*	-4.383186*	-3.938863*	-4.271440*
3	56.56573	0.558161	0.000884	-4.223107	-3.828153	-4.123777
4	59.40664	3.458498	0.000833	-4.272853	-3.927268	-4.185939

**Indicates lag order selected by the criterion*

Source: Author's Compilation using Eviews 10

Table 5 presented the lag order selection by five different criteria. All the lag selection criteria except LR, suggested that a lag length of two (2) is optimal for

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the F-bound cointegration test. Therefore, this study used a lag length of two for the cointegration test.

Bound Test for Cointegration

Bounds Test for cointegration was performed to check the presence of longrun relationship among the variables. The null hypothesis is that there is no long-run relationship among the variables of the study.

Table 6. **Bound Test for Cointegration**

H_0: *No cointegration*

F-Statistic	Significance Level	Bound Critical Values		K
		I(0) Bound	I(1) Bound	
8.814440	1% 2.5%	3.6 3.89	4.9 5.07	4
	5%	3.47	4.57	
	10%	4.4	5.72	

Source: Author's Compilation using Eviews

From the result in table 6, the F-bound test of cointegration shows that, F-statistics is 8.814440 which is higher than both the lower and the upper bound critical values at all the levels of significance. Therefore, the null hypothesis of no cointegration is rejected and concluded that the variables are co-integrated.

Table 7: Result of ARDL model estimation for long-run and Shortrun effects

Variables	Coefficient	Std. Error	t-Statistic	Prob.
FDI	0.022509	0.035257	0.638417	0.0335
LGDPP	-3.763626	2.874813	-1.309173	0.2116
FD	-0.035162	0.022373	-1.571643	0.0138
LPOPG	12.09937	98.51460	1.290157	0.0079
Short-run Estimates **C**	-1113.805	147.9724	-7.527110	0.0000
@TREND	-1.600285	0.212658	-7.525172	0.0000
D(FDI)	-0.583236	0.118004	-4.942528	0.0002
D(FDI(-1))	-0.259375	0.117832	-2.201220	0.0450
D(LGDPP)	-0.382778	0.418316	-0.915046	0.3757

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Variables	Coefficient	Std. Error	t-Statistic	Prob.
D(FD)	2.164050	0.466808	4.635843	0.0004
D(LPOPG)	4.181188	14.83231	0.281897	0.7821
ECM(-1)	-0.492774	0.065463	-7.527566	0.0000
R-squared	0.790038	Mean dependent var	0.009674	
Adjusted R-squared	0.696722	S.D. dependent var	0.084193	
S.E. of regression	0.046366	Akaike info criterion	-3.043303	
Sum squared resid	0.038696	Schwarz criterion	-2.611357	
Log likelihood	50.08459	Hannan-Quinn criter.	-2.914863	
F-statistic	8.466234	Durbin-Watson stat	2.733092	
Prob(F-statistic)	0.000093			

Source: Author's Compilation using Eviews 10

Table 7 presents the result of the ARDL bounds test for the cointegration. In line with the prospects, the outcomes reveal a remarkable positive effect of FDI on CO_2 emissions in Nigeria. Keeping all other variables constant, a 1% increase in FDI increases the CO_2 emissions by about 0.023%. This outcome confirms the validity of the PHH in Nigeria and is conformity with the findings of Zhao & Su, (2023), Huang et al. (2023), Saussay & Zugravu-Soilita, (2023) and Raihan, (2023). However, the result is in contradiction with the works of Leonardoa et al. (2023), Tchouto (2023) and Chen, (2021). The result of the work shows that, the continuous growth of foreign direct investment (FDI) is one of the major sources of environmental deterioration in Nigeria. Besides, the outcome of the FDI's positive effect on CO_2 emissions indicates that the technical impact of FDI is lower than the scale impact. The result depicts a negative relationship between economic growth and CO_2 emissions. A 1% expansion in GDPP reduces CO_2 emissions by 3.76%, keeping other variables constant, and the outcome is not statically significant. This coincides with the findings of Ozkan et al. (2023).

According to the result, the coefficient of financial development is negative and statistically significant. This indicates that at the first stage of financial development (FD), it can deteriorate the environment. More specifically, 1% surge of FD cuts the CO_2 emission by 0.035%, considering other factors constant. This finding is in line with previous studies such as Khan et al. (2021) and Firoj et al. (2023). This result indicates that financial development positively influences the quality of the environment in Nigeria. Thus, environmentally friendly financial

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development may help to reach high economic growth rates. The outcomes also specify that an expansion in population will promote to rise in pollution in Nigeria. Ceteris paribus, 1% increase in the country's population leads to a 12.10% significant increase in carbon emissions.

In the short run, the coefficient of FDI is -0.583, and it is statistically significant, indicating that the pollution haven hypothesis is not supported in the short run. This conclusion is backed by the findings of Firoj et al. (2023). The coefficient of GDPP is -0.383 and statistically insignificant, suggesting that CO2 emission is not affected by GDPP. The finding provides a message of hope that higher economic growth can be achieved without causing environmental degradation. The findings align with that of Okzan et al. (2023). Further, the coefficient of FD is positive and statistically significant. The value of GCF is 2.164, representing that a 1% upsurge in FD escalates the CO2 emissions by 2.16% Ceteris Paribus. Overall, it might be concluded that FD deteriorates the environmental quality of Nigeria in the short run. This result of the present study is similar to the inference of Firoj et al. (2023) in Bangladesh. However, the short-run coefficients of POPG is statistically insignificant, suggesting that population growth does not affect CO2 emissions in the short run. Finally, the ECT is also negative and significant, which further confirms the long-run association between the variables. The value of the coefficient of ECT is – 0.49, indicating that, a shock in the long-run equilibrium of carbon emissions coverage by 49% each year. The result also shows that 79% of variations in the CO2 emissions are accounted for by the changes in the explanatory variables. The Durbin-Watson value of 2.733092 indicating that there is no serial correlation.

Tale 8 Diagnostic Tests

Tests	F- statistics	Obs*R-squared	Prob.
Jaque Bera	---	---	0.532571
Serial Correlation	2.098230	11.76596	0.1787
Heteroskedasticity	0.969456	11.21915	0.5100
RAMSEY RESET	1.768774	---	0.2202

Source: Author's computation using Eviews 10

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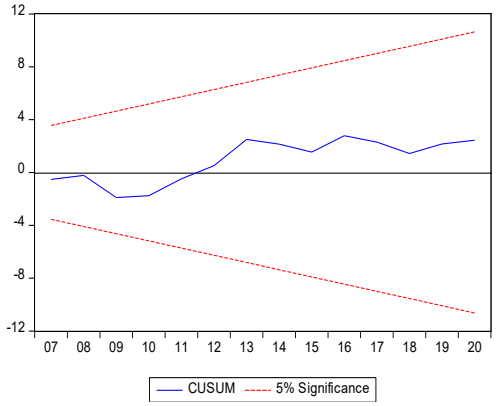


Fig.1 Cusum Test

Source: Author's computation using Eviews 10

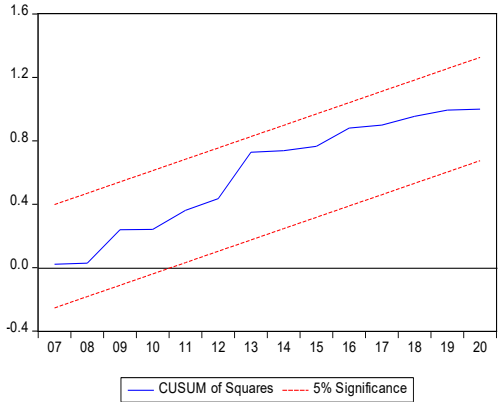


Fig.2 Cusum of Squared Test

Source: Author's computation

The results of diagnostics tests are presented in table 8. The results revealed that the error terms are normally distributed, and the model is free from serial correlation and heteroscedasticity. Also, the model is well specified based on the Ramsey rest test. Similarly, Stability of both the short and long run parameters have been checked using CUSUM and CUSUMsq and the results are presented in Figs. 1 and 2, which showed that the plots are within the 5% critical bounds and justify the stability of the models during the study period.

Conclusion and policy Recommendations

The study examined the impact of foreign direct investment, economic growth, financial development and population growth on CO_2 emissions in order to assess the validity of pollution Haven hypothesis in Nigeria from the year 1980 to 2022. ARDL approach was used in the study to investigate the long run as well as the short-run relationship between the variables. The findings of the study demonstrate that environmental degradation in Nigeria is primarily due to the country's continued rise in foreign direct investment. The result of FDI's positive impact on CO_2 emissions and other factors shows that FDI has a stronger scale impact than technical impact. The negative but insignificant affiliation between GDPP and environmental degradation advocates that economic growth can lead to a durable rise in the standards of living if it is supervised well without any need-less adverse effect on the environmental standard. The negative association between financial development and carbon dioxide emission in Nigeria indicates

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that increasing financial development significantly reduces carbon emissions, while population growth hampers the environmental quality in Nigeria.

Based on the empirical findings, the study recommends the following policy directions. First, as a host country, Nigerian government and policy-makers should enact and strengthen policies, laws, and regulations that require polluting foreign multinational corporations and other foreign investments to pay penalties, such as carbon taxes, to lessen the detrimental effect of FDI on CO_2 emissions. Apart from South Africa, which has a carbon tax system applied, none of the African countries have been enacted such law. Therefore, Nigeria should follow South Africa to aid in mitigating CO_2 emissions. Additionally, investments that deal with clean technologies, green systems, and green development activities should be supported to further aid in attracting clean investments. Secondly, Green finance should be adopted in Nigeria. Green energy is a strategy aimed at sustaining the environment through encouraging consuming less energy and lowering greenhouse gas (GHG) emissions. Therefore, based on the findings of this study, the financial institutions (banks) in Nigeria extending credit to the private sector should apply green finance in the form of green credit to mitigate CO_2 emissions in the country. Finally, it is known fact that, to achieve sustainable development and promote the economy, green technology innovation is paramount. As such, Nigeria hosting such industries that use traditional technologies and emit high amounts of pollutants should practice how to capture, use, and store their emitted CO_2. Applying innovative green technologies, such as carbon capture, usage, and storage, will help protect the environment and progress the country's economy. Thus, the captured carbon can be stored, reused, and recycled to help promote the country's economy and protect the environment.

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