

Public Sector Expenditure and Environmental Quality in Nigeria: The Moderating Role of Corruption

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This study examines the influence of public sector expenditure on environmental quality in Nigeria, with particular attention to the moderating role of Control of Corruption. Annual time-series data covering the period from 1996 to 2023 were obtained from relevant national and international sources. The explanatory variables utilized were public sector expenditure, Control of Corruption and GDP per capita, while carbon dioxide (CO₂) emissions were used as a proxy for environmental quality. Preliminary tests, including unit root and cointegration tests, were conducted before estimating the Autoregressive Distributed Lag (ARDL) model. The unit root results indicate that all the variables are integrated at the first difference, I(1), and none is integrated at the second difference, I(2). The ARDL bounds test confirmed the existence of a long-run relationship among the variables. The long-run estimates indicate that public sector expenditure has a negative and statistically significant effect on CO₂ emissions. Similarly, Control of Corruption has a negative and statistically significant effect on CO₂ emissions, indicating that stronger control of corruption is associated with lower CO₂ emissions. However, the interaction between public sector expenditure and Control of Corruption has a positive and statistically significant effect on CO₂ emissions, confirming that Control of Corruption significantly moderates the relationship between public sector expenditure and environmental quality. In the short run, public sector expenditure and Control of Corruption also exert negative and statistically significant effects on CO₂ emissions, while their interaction remains positive and significant. The error correction term is negative and statistically significant, indicating that approximately 80.7% of short-run disequilibrium is corrected within one period. The study concludes that public sector expenditure is associated with improved environmental quality as measured by CO₂ emissions, while Control of Corruption significantly conditions the relationship between public sector expenditure and environmental quality. The study therefore recommends stronger transparency, accountability and anti-corruption mechanisms, alongside the efficient allocation of public sector expenditure towards environmentally sustainable programmes.

Keywords: Public Sector Expenditure, Environmental Quality, Corruption, CO₂ Emissions, ARDL, Nigeria

Introduction

Environmental quality has become an important concern in development policy as countries seek to expand economic activity without undermining the natural systems that sustain production and human welfare. Economic expansion, urbanization, infrastructure development and rising energy demand have increased pressure on the environment through carbon emissions, resource

depletion and other forms of ecological degradation. The urgency of this challenge is evident worldwide. The United Nations Environment Programme (UNEP, 2024) reports that global greenhouse gas emissions reached a record 57.1 GtCO₂e in 2023, representing a 1.3% increase over 2022. However, current policies remain insufficient for achieving the Paris Agreement temperature objectives, with existing policies related with projected warming of about 3.1°C over the course of the century. The implication is clear: environmental sustainability increasingly depends on the quality of economic and public policy decisions, particularly the way governments allocate and implement public resources.

Public sector expenditure is essential to this discussion because government remains a major provider of infrastructure, energy, transportation, sanitation, environmental protection and other public goods with direct or indirect environmental consequences. Public sector expenditure may improve environmental quality when resources are directed towards clean energy, efficient infrastructure, environmental regulation, waste management and climate-resilient development. It may, therefore, worsen environmental conditions when expenditure finances carbon-intensive infrastructure, inefficient production or poorly regulated economic activities. Thus, the environmental effect of public sector expenditure is fundamentally an empirical question. Recent evidence supports this ambiguity. Suyanto et al. (2024) report that government expenditure increased carbon emissions in G20 countries, while Ağazade (2024) similarly finds that government investment increased environmental pollution in OECD countries. In contrast, Hossain (2024) finds that government expenditure directed towards pollution abatement improved greenhouse-gas productivity in Canada. Ul Hassan et al. (2024) further show that the effectiveness of environmental expenditure in reducing CO₂ emissions depends on governance quality. These divergent findings suggest that the environmental consequences of public sector expenditure depend not only on how much governments spend, but also on where resources are directed and how effectively expenditure is implemented. Among the institutional factors, corruption deserves particular attention because it can distort public procurement, weaken regulatory enforcement, encourage rent-seeking and reduce the efficiency of public sector expenditure. The environmental costs may be especially serious where public resources intended for infrastructure, environmental protection or climate-related programmes are diverted or poorly implemented. Empirical evidence supports this concern. Li et al. (2024), using data for 152 countries, find that stronger control of corruption improves environmental outcomes, particularly among countries with relatively poor environmental quality. Tawiah et al. (2024) also report a negative relationship between corruption and green growth, while Habib, Aksar and Nadeem (2024) find that Control of Corruption is significantly related to environmental outcomes. The implication is that Control of Corruption should not be considered only as an independent determinant of environmental quality; it may also determine whether public sector expenditure produces the environmental outcomes for which it is intended.

This moderating perspective is consistent with recent empirical evidence. Asongu and Ndour (2023), using evidence from 40 Sub-Saharan African countries, show that governance can alter the environmental consequences of military expenditure. Kpegba et al. (2024) similarly find that institutional quality significantly moderates the relationship between public sector expenditure and economic sustainability in Sub-Saharan Africa. More closely related to Nigeria, Ahmadu et al. (2026) find that the interaction between public sector expenditure and corruption has a significant

negative effect on per capita income, implying that corruption reduces the effectiveness of public sector expenditure in generating welfare improvements. Although their study focuses on income rather than environmental quality, it provides important Nigerian evidence that the consequences of public sector expenditure may depend on the level of corruption. The present study extends this reasoning to environmental quality. The Nigerian case is particularly important because the country faces the difficult task of financing development while responding to growing climate and environmental pressures. The World Bank's 2026 Country Climate and Development Report identifies climate change, infrastructure, natural-resource management, energy, urban development and institutional capacity as interconnected components of Nigeria's development challenge. It stresses the need to align development objectives with climate resilience and low-emission development and identifies public administration and investment as important parts of this transition. Nigeria's climate vulnerability is also reflected in the 2025 State of the Climate report of the Nigerian Meteorological Agency (NiMet), which documents changes in temperature and rainfall as well as flooding, drought, coastal erosion and land degradation, with consequences for agriculture, water resources, public health and infrastructure.

At the same time, Nigeria is operating within significant fiscal and development constraints. The World Bank's April 2026 Nigeria Development Update reports that although macroeconomic conditions have improved, household incomes have not fully recovered and poverty remains high. The report emphasises the importance of using available fiscal space more effectively to improve development outcomes. This presents a policy dilemma: Nigeria needs public sector expenditure to address infrastructure and development deficits, yet the environmental implications of such spending depend on its composition, efficiency and institutional governance. Consequently, increasing public sector expenditure without addressing weaknesses in expenditure management and accountability may not yield the desired environmental outcomes. Despite the growing literature on public sector expenditure, governance and environmental quality, an important gap remains. Existing studies have largely examined the direct effects of public sector expenditure on environmental outcomes or the independent effects of corruption and institutional quality. Studies that consider interaction effects generally use broad measures of governance or institutional quality, while country-specific evidence for Nigeria remains limited. In particular, the Nigerian evidence of Ahmadu et al. (2026) establishes that corruption can weaken the effectiveness of public sector expenditure in improving income, but whether the same mechanism operates in the environmental domain remains unanswered. The central issue, therefore, is not simply whether public sector expenditure affects environmental quality, but whether corruption changes the extent to which public sector expenditure translates into environmental improvement or degradation.

Against this background, this study examines public sector expenditure and environmental quality in Nigeria, with particular emphasis on the moderating role of Control of Corruption. Specifically, the study seeks to: (i) examine the effect of public sector expenditure on environmental quality in Nigeria; (ii) determine the effect of Control of Corruption on environmental quality in Nigeria; and (iii) examine whether Control of Corruption moderates the relationship between public sector expenditure and environmental quality in Nigeria. Therefore, addressing these issues within a single framework, the study seeks to contribute country-specific evidence to the growing literature on public sector expenditure, institutional governance and environmental sustainability and to provide policy guidance on how Nigeria can improve the environmental effectiveness of public

resources.

Based on the objectives of the study, the following null hypotheses are formulated and tested empirically:

H₀₁: Public sector expenditure has no significant effect on environmental quality in Nigeria.

H₀₂: Control of Corruption has no significant effect on environmental quality in Nigeria.

H₀₃: Control of Corruption does not significantly moderate the relationship between public sector expenditure and environmental quality in Nigeria.

Literature Review

Conceptual Review

Public Sector Expenditure

Public sector expenditure refers to government spending undertaken to provide public goods and services and to pursue social and economic objectives. It encompasses spending on infrastructure, education, health, transportation, energy, environmental protection and public administration. From an environmental perspective, the relevance of public sector expenditure lies not only in its size but also in its composition and implementation. Expenditure on environmentally sustainable infrastructure, pollution control and efficient public services may support environmental improvement, whereas spending that expands carbon-intensive infrastructure and resource use may increase environmental pressure. Kpegba et al. (2024), for instance, emphasise that the development outcomes of public sector expenditure are closely connected with the institutional conditions under which public resources are managed.

Environmental Quality

Environmental quality describes the condition of the natural environment and the extent to which human activities place pressure on ecological systems. It is a broad concept that encompasses different dimensions of environmental conditions, including air quality, climate-related pollution, resource depletion and ecological sustainability. In empirical research, carbon dioxide emissions and ecological footprint are among the commonly applied indicators because they capture different dimensions of environmental pressure. Carbon dioxide emissions provide an important measure of climate-related environmental degradation, while ecological footprint reflects the demand that human activities place on biologically productive resources. Li et al. (2024), for example, employ both carbon emissions and ecological footprint to examine environmental quality across 152 countries, demonstrating the usefulness of considering different indicators when assessing environmental degradation. In the present study, carbon dioxide (CO₂) emissions are used as the empirical proxy for environmental quality. Accordingly, lower CO₂ emissions are interpreted as an improvement in the environmental quality dimension captured by the study, while higher CO₂ emissions indicate greater environmental degradation.

Corruption

Corruption refers to the misuse of entrusted authority for private gain and is particularly relevant to public resource management because it can distort the allocation and implementation of public

sector expenditure. Corruption may operate through bribery, procurement irregularities, diversion of resources and preferential allocation of public contracts. These practices can weaken the capacity of government institutions to implement public programmes effectively and to enforce environmental standards. From an empirical perspective, however, corruption may be measured either directly or through indicators of institutional control over corrupt practices. In this study, the Control of Corruption indicator from the Worldwide Governance Indicators (WGI) is used to capture the institutional control dimension of corruption. Higher values of the Control of Corruption indicator represent stronger control of corruption, while lower values indicate weaker control. Li et al. (2024) incorporate corruption control directly into their analysis of environmental quality and examine its relationship with both carbon emissions and ecological footprint. Their approach reinforces the importance of governance conditions in understanding environmental outcomes. Accordingly, the present study focuses on Control of Corruption rather than interpreting the CROP variable as a direct measure of the prevalence of corruption.

Theoretical Review: Institutional Theory

Institutional Theory provides the theoretical foundation for this study because it explains how the rules, structures and governance arrangements within which public resources are allocated and implemented influence economic and environmental outcomes. North (1990) argues that institutions establish formal and informal rules that shape incentives, constrain behaviour and influence the efficiency with which resources are utilised. From this perspective, the environmental effect of public sector expenditure cannot be understood solely from the amount of resources committed by government; it also depends on the institutional environment governing their allocation, implementation and monitoring. The relevance of Institutional Theory to public sector expenditure and environmental quality arises from the fact that public expenditure is implemented through institutional arrangements involving budgeting, procurement, project execution, regulation and monitoring. Where these institutions are effective, public resources are more likely to be allocated according to established priorities and used for their intended purposes. Consequently, expenditure on infrastructure, environmental protection, public transportation, energy efficiency, sanitation and other public services is more likely to generate the intended environmental benefits. Conversely, weak institutional controls may reduce the effectiveness of public sector expenditure through inefficient allocation, resource diversion, procurement irregularities and weak enforcement of environmental regulations.

Control of Corruption represents an important institutional mechanism within this framework. Where corruption is poorly controlled, public officials may have greater opportunities to divert resources, manipulate procurement processes or favour inefficient projects. Such practices can reduce the amount and quality of public goods generated from a given level of expenditure and may weaken the environmental benefits expected from public sector expenditure. In contrast, stronger Control of Corruption can strengthen accountability and constrain opportunistic behaviour, thereby increasing the likelihood that public resources are used for their intended purposes. This institutional mechanism is consistent with Li et al. (2024), who demonstrate the relevance of corruption control to environmental outcomes, and Kpegba et al. (2024), who show that institutional quality can condition the effects of public expenditure on development outcomes. Institutional Theory therefore provides a direct theoretical basis for the moderating relationship examined in this study. The theory implies that the environmental effect of public sector

expenditure is not necessarily constant across different institutional environments. Rather, the effect of expenditure may depend partly on the extent to which institutional mechanisms constrain corruption and ensure accountability in the use of public resources. Thus, Control of Corruption is expected to alter the magnitude of the relationship between public sector expenditure and CO₂ emissions, where CO₂ emissions serve as the empirical proxy for environmental quality. The theoretical relationship can therefore be expressed as: Environmental Quality = f(Public Sector Expenditure, Control of Corruption, Public Sector Expenditure × Control of Corruption, GDP per capita). The interaction term LGEXP × CROP is derived directly from this theoretical proposition. Its inclusion in the empirical model allows the study to test whether the effect of public sector expenditure on CO₂ emissions changes as the level of Control of Corruption changes. A statistically significant interaction coefficient would indicate that institutional conditions systematically modify the environmental consequences of public sector expenditure. The direction of the interaction coefficient is ultimately an empirical matter because the environmental consequences of public expenditure depend on both the composition of expenditure and the institutional conditions under which it is implemented. Thus, Institutional Theory leads directly to the study's moderating hypothesis that the effect of public sector expenditure on environmental quality in Nigeria depends on the level of Control of Corruption. This proposition provides the theoretical justification for incorporating the interaction between LGEXP and CROP into the ARDL model and for testing whether Control of Corruption significantly conditions the relationship between public sector expenditure and CO₂ emissions.

Empirical Review

Several recent studies have examined the relationship between public expenditure, environmental quality, institutional quality and corruption, although their findings remain mixed. For instance, Asongu and Ndour (2023) investigated military expenditure, governance and environmental degradation in 40 Sub-Saharan African countries using GMM estimation over 2010–2020. The study found that military expenditure increased CO₂ emissions, while improved governance mitigated the adverse environmental consequences of military expenditure. Similarly, Tawiah et al. (2023/2024) examined corruption and green growth using an unbalanced panel of 123 countries from 2000–2017 and found that corruption was negatively associated with green growth, with the effect being stronger among developing countries. These findings indicate that both public expenditure and institutional conditions can influence environmental sustainability. Other studies have produced evidence on the direct relationship between government expenditure and environmental outcomes. Suyanto et al. (2024) examined 19 G20 countries using panel data covering 1995–2015 within the Environmental Kuznets Curve framework. The study found that institutional quality reduced carbon emissions, whereas government expenditure increased carbon emissions. In contrast, Hossain (2024) investigated government spending on pollution abatement and green growth in ten Canadian provinces over 1995–2020 using a STIRPAT-based framework. The study found that pollution-abatement expenditure had a positive and statistically significant effect on greenhouse-gas productivity, suggesting that the composition and purpose of government expenditure are important in determining environmental outcomes. Similarly, Ağazade (2024) examined government investments and environmental pollution in 38 OECD countries over 2007–2020 using System GMM and found that government investments increased environmental pollution. The study further showed that industrial production and energy intensity increased emissions, while renewable energy reduced them. These contrasting findings

suggest that government expenditure does not have a uniform environmental effect across countries and that the nature and allocation of expenditure may matter. The role of governance and corruption in determining environmental outcomes has also received considerable attention. Li et al. (2024) examined natural resource rents, corruption control and environmental quality in 152 countries over 2002–2018 using moment quantile regression. The study found that corruption control improved environmental conditions, particularly among countries with relatively poor environmental quality, while the effect of natural resource rents varied across different levels of environmental quality. Likewise, Habib et al. (2024) examined control of corruption, green finance and environmental upgrading in ten developed economies over 2000–2018 using System GMM. The findings indicated that green finance reduced ecological footprint and carbon emissions, while control of corruption significantly influenced environmental outcomes. These studies provide evidence that institutional quality and corruption control are important determinants of environmental performance. The interaction between public expenditure and institutional quality has also been examined. Kpegba et al. (2024) investigated whether institutional quality moderates the relationship between public expenditure and economic sustainability in 48 Sub-Saharan African countries over 2003–2022 using Pooled OLS and System GMM. The findings showed that public expenditure and institutional quality individually had positive and statistically significant effects on economic sustainability, while institutional quality had a negative and statistically significant moderating effect on the relationship between public expenditure and economic sustainability. Similarly, Ul et al. (2024) examined governance, government environmental expenditure and CO₂ emissions in the BRIC economies over 1996–2020 using FMOLS and marginal-effects analysis. The study found that environmental expenditure could reduce CO₂ emissions, but its effectiveness depended on governance quality. These findings suggest that the environmental consequences of public expenditure may depend on the institutional environment in which public resources are managed.

Evidence from Nigeria also supports the importance of examining public expenditure alongside institutional factors. Ahmadu et al. (2026) examined government expenditure and per capita income in Nigeria using annual data for 1996–2023 and the ARDL approach. The study found that government expenditure had a positive and statistically significant long-run effect on per capita income, although its short-run effect was negative and significant. Ahmadu et al. (2026) further examined government expenditure, corruption and income in Nigeria using ARDL and Toda–Yamamoto causality techniques over the same period. The findings showed that government expenditure had a positive and significant effect on per capita income in the long run, while the interaction between government expenditure and corruption was negative and statistically significant, indicating that corruption reduced the effectiveness of government expenditure in improving income. These findings are important to the present study because they demonstrate that the impact of public expenditure in Nigeria may depend on institutional conditions. The empirical literature provides no uniform conclusion regarding the effect of public expenditure on environmental quality. While Hossain (2024) and Ul et al. (2024) reported environmentally beneficial effects of targeted government expenditure, Suyanto et al. (2024) and Ağazade (2024) found that government expenditure or investment could increase environmental pollution. Similarly, the evidence on corruption and institutional quality generally indicates that stronger corruption control and better governance improve environmental outcomes, while corruption undermines green growth. However, relatively limited attention has been given to whether

corruption specifically moderates the effect of aggregate public sector expenditure on environmental quality, particularly in Nigeria.

Gaps in the Literature

The gaps in the literature identified by this study are in two folds. Firstly, from the empirical and contextual perspective, most existing studies have examined developed countries, groups of countries or broad international samples. For example, Suyanto et al. (2024) focused on 19 G20 countries, Li et al. (2024) examined 152 countries, Habib et al. (2024) focused on ten developed economies, Ağazade (2024) investigated 38 OECD countries, while Ul et al. (2024) examined the BRIC economies. Although Kpegba et al. (2024) focused on 48 Sub-Saharan African countries, the study examined economic sustainability rather than environmental quality. Consequently, there remains limited country-specific evidence on how public sector expenditure affects environmental quality in Nigeria, particularly when corruption is explicitly incorporated as a moderating factor. Secondly, from the conceptual and methodological perspective, existing studies have largely examined the independent effects of public expenditure, governance or corruption on environmental outcomes. Studies such as Li et al. (2024) and Habib et al. (2024) focused on corruption control and environmental quality, while Suyanto et al. (2024), Hossain (2024) and Ağazade (2024) concentrated on government expenditure or investment and environmental outcomes. Although Kpegba et al. (2024) and Ul et al. (2024) provided evidence that institutional conditions can alter the effect of public expenditure on development or environmental outcomes, their analyses did not specifically examine the interaction between aggregate public sector expenditure and corruption in determining environmental quality in Nigeria. Similarly, the Nigerian study by Ahmadu et al. (2026) examined the interaction between government expenditure and corruption, but its outcome variable was per capita income rather than environmental quality. Therefore, this study fills the gap by integrating public sector expenditure, corruption and their interaction into a single framework and examining their effects on CO₂ emissions in Nigeria using annual time-series data for 1996–2023 and the ARDL approach. This approach makes it possible to determine not only the direct effect of public sector expenditure and corruption on environmental quality but also whether corruption changes the environmental consequences of public spending in Nigeria.

Methodology

Research Design and Data Sources

The study adopts a quantitative ex-post facto research design based on annual time-series data for Nigeria. The study uses secondary data covering the period **1996–2023**, subject to data availability. Data on public sector expenditure, environmental quality, corruption and the selected control variables are obtained from reputable national and international databases, including the World Bank, Worldwide Governance Indicators (WGI), and other relevant official sources. Corruption is measured using the Control of Corruption (CROP) indicator obtained from the World Bank's Worldwide Governance Indicators (WGI). The indicator captures the extent to which public authority is exercised for private gain, including both minor and major forms of corruption, as well as the extent to which the state is subject to elite capture and private interests. The study uses the indicator consistently as a measure of the institutional control of corruption.

Importantly, the direction of the indicator is taken into account in interpreting the estimated coefficients. A higher value of the Control of Corruption indicator represents stronger control of corruption, while a lower value represents weaker control of corruption and a greater prevalence of corruption. Accordingly, CROP should not be interpreted as a direct measure in which an increase necessarily means an increase in corruption. Rather, an increase in CROP represents an improvement in the control of corruption. The corruption variable is entered into the empirical model together with public sector expenditure and their interaction term, (LGEXP*CROP), to determine whether the effectiveness of public expenditure in influencing environmental quality depends on the prevailing level of corruption control. The same coding and direction of measurement are maintained throughout the model specification, estimation, results and discussion. Where the original WGI indicator has been transformed for estimation, the transformation is applied consistently to all observations and the resulting values are used in the ARDL estimation. The transformation does not alter the substantive direction of the indicator; therefore, higher values continue to represent stronger control of corruption.

Model Specification

The study examines the effect of public sector expenditure on environmental quality in Nigeria and specifically investigates whether corruption control moderates the relationship between public sector expenditure and environmental quality. Environmental quality is represented by carbon dioxide (CO₂) emissions, while public sector expenditure is the main explanatory variable. Control of corruption is introduced as the moderating variable, and GDP per capita is included as a control variable. The functional relationship between the variables is specified as:

$$CO2_t = LGEXP_t, CROP_t, LGEXP_t * CROP_t, LGDPP_t \quad 1$$

Where (CO_{2t}) represents carbon dioxide emissions and serves as the measure of environmental quality, (LGEXP_t) represents public sector expenditure; (CROP_t) represents Control of Corruption; (LGEXP * CROP) represents the interaction between public sector expenditure and Control of Corruption; (LGDPP_t) represents GDP per capita; and (t) denotes time.

A Priori Expectation

Based on the theoretical and empirical literature reviewed in the study, public sector expenditure is expected to influence environmental quality, although the direction of the effect may depend on the composition and efficiency of government spending. Stronger Control of Corruption is expected to contribute to better environmental outcomes by improving the allocation and implementation of public resources and strengthening compliance with environmental regulations. The interaction between public sector expenditure and Control of Corruption is therefore expected to be statistically significant if institutional quality conditions the effectiveness of public expenditure in influencing environmental quality. The expected sign of the interaction coefficient depends on the direction in which Control of Corruption changes the marginal effect of public expenditure on CO₂ emissions. The econometric model is specified as:

$$CO2 = \alpha_0 + \alpha_1 LGEXP_t + \alpha_2 CROP_t + \alpha_3 LGEXP_t * CROP_t + \alpha_4 LGDPP_t + \mu_t \quad 2$$

where (α_0) is the intercept; (α_1) measures the direct effect of public sector expenditure on CO₂

emissions; (α_2) captures the direct effect of Control of Corruption on CO₂ emissions; (α_3) captures the moderating effect of Control of Corruption on the relationship between public sector expenditure and CO₂ emissions; (α_4) measures the effect of GDP per capita on CO₂ emissions; and (μ_t) is the error term. The inclusion of the interaction term (LGEXPt*CROPt) is central to testing the moderating role of corruption control. Since the study uses an autoregressive distributed lag (ARDL) framework, the above long-run relationship is estimated alongside the associated short-run dynamics. The ARDL specification incorporates the lagged values of the dependent and explanatory variables to capture both the short-run adjustments and long-run equilibrium relationship among public sector expenditure, Control of Corruption, the interaction term and GDP per capita. The bounds testing procedure is subsequently used to determine whether a long-run relationship exists among the variables. For the present study, the interaction term is therefore not treated merely as an additional explanatory variable. Its statistical significance is used to establish whether Control of Corruption systematically changes the effect of public sector expenditure on CO₂ emissions. This specification directly addresses the central objective of the study concerning the moderating role of corruption in the public expenditure–environmental quality relationship.

Data Sources

This study employs secondary annual time-series data spanning from 1996–2023, obtained from the World Bank and examines the influence of public sector expenditure on environmental quality in Nigeria, with particular emphasis on the moderating role of corruption.

Pre-estimation Tests

The data obtained for this study were subjected to pre-estimation tests, including trend analysis, stationarity tests using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, and cointegration test to determine the order of integration of the series and establish whether a long-run relationship exists among the variables. The results of these pre-estimation tests provide the basis for selecting the appropriate estimation technique for examining the relationship between public sector expenditure, environmental quality, corruption and GDP per capita in Nigeria

Estimation Technique

The Autoregressive Distributed Lag (ARDL) model was employed in this study, following the results of the pre-estimation tests, which indicated that the variables were integrated at different levels, I(0) and I(1), with none integrated at I(2). The ARDL model is appropriate for analysing relationships among variables with a combination of I(0) and I(1) series and allows the study to examine both short-run and long-run relationships among public sector expenditure, environmental quality, corruption and GDP per capita. The ARDL bounds testing approach is first employed to establish whether a long-run relationship exists among the variables. Where cointegration is confirmed, the ARDL long-run coefficients and the associated short-run Error Correction Model (ECM) are estimated to determine the speed at which short-run deviations adjust towards long-run equilibrium. The approach is particularly suitable for this study because it provides a unified framework for examining both the short-run and long-run effects of public sector expenditure and corruption on environmental quality in Nigeria. Below are the Autoregressive Distributed Lag models for the long run, bound test and the short run model specifications for equation 3

$$\Delta \text{CO}_2_t = \alpha_0 + \alpha_1 \text{CO}_2_{t-1} + \alpha_2 \text{LGEXP}_{t-i} + \alpha_3 \text{CROP}_{t-i} + \alpha_4 \text{LGEXP} * \text{CROP}_{t-i} + \alpha_5 \text{LGDP}_{t-t} \\ + \sum_{i=0}^v \theta_{1i} \Delta \text{CO}_2_{t-1} + \sum_{i=0}^{v_1} \theta_{2i} \Delta \text{LGEXP}_{t-i} + \sum_{i=0}^{v_2} \theta_{3i} \Delta \text{CROP}_{t-i} + \sum_{i=0}^{v_3} \theta_{4i} \Delta \text{LGEXP} * \text{CROP}_{t-i} \\ + \sum_{i=0}^{v_5} \theta_{4i} \Delta \text{LGDP}_{t-i} + \lambda \text{ECM}(-1) + u_i$$

3

Where: $\lambda < 0$ indicates speed of adjustment coefficient.

The study uses annual time-series data covering the period **1996–2023**. The period is selected based on data availability consistency and to capture structural changes in Nigeria's fiscal and macroeconomic environment, including democratic transition and fiscal reforms.

Presentation of Results and Discussions

Descriptive Statistics

Table 1. Descriptive Statistics

Statistic	CO2	GEXP	CROP	GDPP
Mean	0.662143	5116.204	20.81786	2049.786
Maximum	0.940000	20510.00	28.00000	2585.734
Minimum	0.530000	124.5000	6.900000	1390.469
Std. Dev.	0.121788	5324.632	6.039626	413.1238

Source: Estimated by Author, 2026

Table 1 presents the descriptive statistics of the variables used in the study. The mean values of CO₂, GEXP, CROP and GDPP are 0.6621, 5,116.204, 20.8179 and 2,049.786, respectively, while their standard deviations are 0.1218, 5,324.632, 6.0396 and 413.1238. CO₂ ranges from 0.53 to 0.94, GEXP from 124.50 to 20,510.00, CROP from 6.90 to 28.00, and GDPP from 1,390.469 to 2,585.734. The results show considerable variation in public sector expenditure and corruption compared with CO₂ emissions, while GDP per capita exhibits relatively lower dispersion around its mean during the study period.

Correlation Matrix

Table 2: Correlation Matrix

Variable	CO2	GEXP	CROP	GDPP
CO2	1.000000			
GEXP	-0.654180	1.000000		
CROP	-0.904186	0.605511	1.000000	
GDPP	-0.882082	0.585557	0.898497	1.000000

Source: Estimated by Author, 2026

Table 2 presents the correlation matrix among the variables. The results show that CO₂ is negatively correlated with GEXP (-0.6542), CROP (-0.9042), and GDPP (-0.8821), indicating that increases in these variables are associated with decreases in CO₂ emissions at the bivariate level. Conversely, GEXP is positively correlated with CROP (0.6055) and GDPP (0.5856), while CROP has a strong positive correlation with GDPP (0.8985). Overall, the correlation results suggest relatively strong associations among some explanatory variables, particularly CROP and GDPP, which may warrant further assessment for possible multicollinearity using appropriate diagnostic tests.

Table 3: Variance Inflation Factor (VIF) Test for Multicollinearity

Explanatory Variable	VIF	Tolerance
LGEXP	1.60	0.624
CROP	5.46	0.183
LGDPP	5.26	0.190
Mean VIF	4.11	

Source: Estimated by Author, 2026

The VIF results indicate that **LGEXP has a low VIF of 1.60**, while **CROP and LGDPP record VIF values of 5.46 and 5.26, respectively**, reflecting moderate collinearity between control of corruption and GDP per capita, consistent with the relatively high correlation of 0.8985 reported in the correlation matrix. Nevertheless, all the VIF values remain below the commonly applied critical threshold of 10, while the mean VIF of 4.11 also suggests that **multicollinearity is not sufficiently severe to invalidate the estimated coefficients or pose a serious threat to the reliability of the ARDL estimates**. Thus, although some degree of association exists among the explanatory variables, particularly between CROP and LGDPP, the VIF evidence indicates that multicollinearity does not constitute a major problem in the estimated model.

Unit Root Tests

Table 4: Unit Root Tests

Variable	ADF Statistic (Level)	Test Statistic (First Diff.)	PP Statistic (Level)	Test Statistic (First Diff.)	Decision
CO2	-2.161975 (0.2239)	-6.066752 (0.0000)***	-2.395540 (0.1523)	-6.287357 (0.0000)***	I(1)
LGEXP	-2.633735 (0.0988)*	-3.198678 (0.0316)**	-2.474904 (0.1324)	-3.186034 (0.0325)**	I(1)
CROP	-2.414080 (0.1474)	-5.839385 (0.0001)***	-2.387098 (0.1545)	-5.757228 (0.0001)***	I(1)
LGDPP	-1.878207 (0.3367)	-2.091642 (0.0372)**	-1.619139 (0.4594)	-1.991793 (0.0462)**	I(1)

Source: Estimated by Author, 2026

The stationarity properties of the variables were examined using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The decision rule was based on the combined evidence from both tests, with a variable classified as I(0) only when there was sufficient evidence of stationarity at level, while a variable was classified as I(1) when it became stationary after first differencing. Although LGEXP is statistically significant at the 10% level in the ADF test at level ($p = 0.0988$), the Phillips-Perron test does not reject the null hypothesis of a unit root at level ($p = 0.1324$). Consequently, the evidence does not provide sufficiently consistent support for classifying LGEXP as I(0). Since LGEXP, like CO₂, CROP and LGDPP, becomes stationary after first differencing, the final decision is to classify all the variables as I(1). Importantly, none of the variables is integrated of order two, I(2), which satisfies the principal stationarity requirement for the application of the ARDL bounds-testing approach. Therefore, the study does not describe the variables as “predominantly I(1)”; rather, based on the final decision rule and the combined ADF and PP evidence, all variables are classified as I(1). The unit-root tests indicate that all variables are

integrated of order one, I(1), with none integrated of order two, I(2), thereby supporting the application of the ARDL bounds-testing approach.”

4.4 ARDL Bounds Test

Table 5: ARDL Cointegration Test (Bounds Test)

F-Bounds Test	Null Hypothesis: No levels relationship			
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	7.510867			
		10%	2.525	3.56
		5%	3.058	4.223
		1%	4.28	5.84

Source: Estimated by Author, 2026

Table 5 presents the ARDL Bounds Test for cointegration, with the null hypothesis stating that there is no levels relationship among the variables. The result shows that the calculated F-statistic of 7.510867 is greater than the upper-bound critical value of 5.84 at the 1% level of significance. Similarly, the calculated F-statistic exceeds the upper-bound critical values of 4.223 and 3.56 at the 5% and 10% levels, respectively. Since the F-statistic is greater than the I(1) upper-bound critical value at all the reported significance levels, the null hypothesis of no levels relationship is rejected. This indicates the existence of a long-run cointegration relationship among CO₂ emissions, public sector expenditure, corruption and GDP per capita in Nigeria. The result therefore provides sufficient evidence to proceed with the estimation of the long-run and short-run ARDL models to determine the nature and magnitude of the relationships among the variables

Long-Run ARDL

Table 6. Long-Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LGEXP	-0.683231	0.199156	-3.430637	0.0025
CROP	-0.103435	0.030909	-3.346478	0.0031
LGEXP*CROP	0.025848	0.008479	3.048644	0.0061
LGDPP	0.710566	0.395785	1.795334	0.0870
C (Constant)	0.892676	0.856449	1.042298	0.3091

Source: Estimated by Author, 2026

The long-run ARDL estimates show that public sector expenditure (LGEXP) has a negative and statistically significant effect on CO₂ emissions, with a coefficient of -0.683231 and a probability value of 0.0025. This implies that a 1% increase in public sector expenditure is associated with approximately a 0.68% reduction in CO₂ emissions in the long run, holding other variables constant. The result indicates that increased public sector expenditure is associated with improved environmental quality in Nigeria over the long run. This finding is consistent with Hossain (2024), who found that government expenditure on pollution abatement had a positive and statistically significant effect on greenhouse-gas productivity in Canada. It is also consistent with Ul et al. (2024), who found that environmental expenditure could contribute to reducing CO₂ emissions in the BRIC economies, although the effectiveness of expenditure depended on governance quality. However, the finding differs from Suyanto et al. (2024), who reported that government expenditure increased carbon emissions across 19 G20 countries, and Ağazade (2024), who found that government investments increased environmental pollution across 38 OECD countries. The

differences may be associated with variations in the composition of public expenditure, institutional conditions and country-specific economic structures. The Nigerian evidence therefore suggests that, in the long run, public sector expenditure is associated with environmental improvement, as measured by lower CO₂ emissions, rather than environmental deterioration.

The long-run ARDL result shows that the coefficient of Control of Corruption (CROP) is negative and statistically significant at the 1 percent level ($\beta = -0.103435$; $p = 0.0031$). This indicates that stronger Control of Corruption is associated with a reduction in CO₂ emissions in Nigeria in the long run. Specifically, a one-unit increase in the Control of Corruption indicator is associated with approximately a 0.103-unit decline in CO₂ emissions, holding other variables constant. The result suggests that stronger institutional control of corruption can contribute to improved environmental outcomes by reducing opportunities for diversion of public resources, procurement irregularities and weak enforcement of environmental regulations. Thus, the coefficient should be interpreted as evidence that stronger Control of Corruption is associated with better environmental outcomes, rather than as evidence that greater corruption improves environmental quality. This finding agrees with Li et al. (2024), who reported that corruption control improved environmental conditions, particularly in countries with relatively poor environmental quality. It is also consistent with Habib et al. (2024), who found that Control of Corruption significantly influenced environmental outcomes. The result therefore supports the view that stronger institutional control over corruption can contribute to improved environmental quality.

The long-run coefficient of the interaction between public sector expenditure and Control of Corruption (LGEXP*CROP) is positive and statistically significant ($\beta = 0.025848$; $p = 0.0061$). This result provides empirical evidence that Control of Corruption significantly moderates the relationship between public sector expenditure and CO₂ emissions in Nigeria. The significance of the interaction coefficient indicates that the environmental effect of public sector expenditure varies according to the level of Control of Corruption. The marginal effect of public sector expenditure on CO₂ emissions is given by: $\partial \text{CO}_2 / \partial \text{LGEXP} = -0.683231 + 0.025848(\text{CROP})$. This marginal-effect expression shows that the negative direct coefficient of public sector expenditure should not be interpreted independently of the moderating variable. The positive interaction coefficient indicates that as the CROP value increases, representing stronger Control of Corruption, the marginal effect of public sector expenditure on CO₂ emissions becomes less negative, or more positive. Therefore, Control of Corruption significantly changes the strength of the relationship between public sector expenditure and CO₂ emissions. The significant interaction coefficient provides direct evidence of moderation because it demonstrates that the effect of public sector expenditure is conditional on the level of Control of Corruption. The estimated marginal effect further indicates that the expenditure effect is not constant across different levels of Control of Corruption. At lower values of CROP, representing weaker Control of Corruption, the negative effect of public sector expenditure on CO₂ emissions is stronger. As CROP increases, indicating stronger Control of Corruption, the marginal effect moves toward zero, implying that the emissions-reducing effect associated with additional public sector expenditure becomes progressively weaker. At sufficiently high values of CROP, the marginal effect could potentially become positive, indicating that additional public sector expenditure may be associated with higher CO₂ emissions. The implied turning point is approximately 26.43 units of the CROP measure. However, this threshold should be interpreted cautiously and only within the observed range of the Control of Corruption variable. More importantly, the positive interaction coefficient

should not be interpreted as evidence that stronger Control of Corruption necessarily worsens environmental quality. Rather, it indicates that the effect of public sector expenditure on CO₂ emissions changes as the institutional environment changes. The finding confirms the central proposition of the study that the environmental consequences of public sector expenditure depend partly on the institutional environment within which public resources are allocated and implemented. Importantly, it is the statistical significance of the interaction coefficient, rather than the significance of the CROP coefficient alone, that establishes the presence of moderation in the model. This result is consistent with Kpegba et al. (2024), who found that institutional quality significantly moderated the relationship between public expenditure and economic sustainability in Sub-Saharan Africa. Although their study focused on economic sustainability rather than environmental quality, their finding supports the argument that the effect of public expenditure depends on the institutional environment. The present result provides an institutional explanation for why the environmental effect of public sector expenditure may vary across different levels of Control of Corruption. Although public sector expenditure has a negative and significant direct effect on CO₂ emissions, its environmental effect is not uniform across different institutional conditions. The positive and significant interaction coefficient indicates that the emissions-reducing effect of public sector expenditure becomes weaker as the CROP value increases. This suggests that the environmental consequences of public expenditure depend not only on the amount of resources committed but also on the institutional conditions governing their allocation, implementation and monitoring.

This finding is also consistent with Ul et al. (2024), who found that the effectiveness of environmental expenditure in reducing CO₂ emissions depended on governance quality. Similarly, Asongu and Ndour (2023) reported that improved governance could mitigate the adverse environmental consequences of military expenditure in Sub-Saharan Africa. The present finding extends these results by demonstrating that Control of Corruption specifically conditions the relationship between aggregate public sector expenditure and environmental quality in Nigeria. Furthermore, the finding complements the evidence of Ahmadu et al. (2026), who found that the interaction between government expenditure and corruption had a negative and statistically significant effect on per capita income in Nigeria. While Ahmadu et al. (2026) established that corruption reduces the welfare-enhancing effectiveness of government expenditure, the present study shows that the institutional control of corruption changes the environmental consequences of public expenditure. The difference in the signs of the interaction coefficients is understandable because the two studies examine different dependent variables and therefore capture different dimensions of development. GDP per capita (LGDP) has a positive coefficient of 0.710566 and a probability value of 0.0870. The result indicates that a 1% increase in GDP per capita is associated with approximately a 0.71% increase in CO₂ emissions in the long run, holding other variables constant. Although the coefficient is not statistically significant at the 5% level, it is statistically significant at the 10% level. The positive relationship suggests that increases in income may be accompanied by greater environmental pressure in Nigeria, potentially reflecting increased production, consumption, and energy use and investment activities. The finding is broadly comparable with Suyanto et al. (2024) and Ağazade (2024), whose findings point to environmental pressures associated with economic and investment activities. Nevertheless, the evidence should be interpreted with the appropriate significance level: the estimated income effect is statistically supported at the 10% level but not at the conventional 5% level

Short-Run ARDL

Table 7. Short-Run Dynamics (Error Correction Model)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CointEq(-1)*	-0.807446	0.108097	-7.469606	0.0000
Δ LGEXP	-0.551672	0.157660	-3.499114	0.0021
Δ CROP	-0.083518	0.023029	-3.626673	0.0016
Δ (LGEXP*CROP)	0.020871	0.006319	3.302996	0.0034
Δ LGDP	0.573743	0.307236	1.867434	0.0759
C	0.720787	0.722765	0.997263	0.3300

Source: Estimated by Author, 2026

The short-run Error Correction Model (ECM) results presented in Table 6 show that the coefficient of the error correction term, CointEq(-1), is -0.807446 with a probability value of 0.0000, indicating that it is negative and statistically significant at the 1% level. The negative and significant coefficient confirms the existence of a stable long-run relationship among the variables and indicates that approximately 80.7% of short-run deviations from the long-run equilibrium are corrected within one period. This relatively high speed of adjustment implies that disturbances in the relationship between public sector expenditure, corruption, their interaction and GDP per capita are corrected fairly rapidly, with the system returning towards its long-run equilibrium.

The short-run coefficient of the change in public sector expenditure (Δ LGEXP) is -0.551672, with a probability value of 0.0021, indicating a negative and statistically significant effect at the 1% level. This implies that a 1% increase in public sector expenditure is associated with approximately a 0.55% reduction in CO₂ emissions in the short run, ceteris paribus. The finding indicates that public sector expenditure contributes to an improvement in environmental quality not only in the long run but also during short-run adjustments. This result is consistent with Hossain (2024), who found that government expenditure on pollution abatement significantly improved greenhouse-gas productivity. It also agrees with Ul et al. (2024), who reported that environmental expenditure could reduce CO₂ emissions, although the effectiveness of expenditure was conditioned by governance quality. However, it differs from Suyanto et al. (2024) and Ağazade (2024), who found that government expenditure or government investment increased environmental pollution. The difference may reflect differences in the composition of public expenditure and the institutional and economic contexts examined.

The short-run change in corruption (Δ CROP) has a coefficient of -0.083518 and a probability value of 0.0016, showing a negative and statistically significant effect at the 1% level. Thus, a one-unit increase in the corruption variable is associated with approximately a 0.084-unit reduction in CO₂ emissions in the short run, holding other factors constant. As with the long-run result, the substantive interpretation depends on how the corruption indicator is coded. If a higher value represents stronger control of corruption, the result suggests that a one-unit improvement in corruption control is associated with a 0.084-unit reduction in CO₂ emissions. This finding is consistent with Li et al. (2024), who found that corruption control improved environmental conditions, and with Habib et al. (2024), who established that control of corruption significantly influenced environmental outcomes. The result reinforces the relevance of institutional control in explaining short-run environmental outcomes. The short-run interaction coefficient between public sector expenditure and Control of Corruption is positive and statistically significant ($\beta = 0.020871$; $p = 0.0034$). This indicates that Control of Corruption also significantly moderates the short-run

relationship between public sector expenditure and CO₂ emissions. The marginal short-run effect of public sector expenditure is therefore conditional on the level of Control of Corruption. The positive interaction coefficient implies that an increase in the CROP measure makes the short-run emissions effect of public sector expenditure less negative or more positive. The consistency of the statistically significant interaction term in both the long run and short run demonstrates that the relationship between public sector expenditure and environmental quality is institutionally conditioned rather than constant across different levels of Control of Corruption. This result is consistent with Kpegba et al. (2024), who found that institutional quality significantly moderated the relationship between public expenditure and economic sustainability in Sub-Saharan Africa. It also agrees with Ul et al. (2024), whose findings indicated that the environmental effectiveness of government expenditure depended on governance quality. Similarly, Asongu and Ndour (2023) found that governance could moderate the environmental consequences of public expenditure, although their study focused specifically on military expenditure. The present finding extends this evidence by demonstrating that corruption significantly conditions the environmental consequences of aggregate public sector expenditure in Nigeria. The coefficient of the change in GDP per capita (Δ LGDP) is 0.573743, with a probability value of 0.0759. The coefficient is positive but statistically insignificant at the 5% level, although it would be considered significant at the 10% level. The result implies that a 1% increase in GDP per capita is associated with approximately a 0.57% increase in CO₂ emissions in the short run, *ceteris paribus*. However, because the probability value is greater than 0.05, the study does not provide sufficient evidence to establish a statistically significant short-run effect at the conventional 5% level. The positive direction is broadly consistent with the environmental pressure associated with economic activities reported by Suyanto et al. (2024) and Ağazade (2024). Nevertheless, the present result differs in statistical significance because GDP per capita is also insignificant at the 5% level in the long-run estimates.

Diagnostic Tests

Table 8. Diagnostic Tests

Test	Statistic	p-value
R-squared	0.9238	-
F-statistic	50.92443	0.0000
Durbin-Watson stat	2.6158	-
Breusch-Godfrey Serial Correlation LM	F(2,12)=1.3258	0.3018
Breusch-Pagan-Godfrey Heteroskedasticity	F(5,21)=1.3521	0.2818

Source: Estimated by Author, 2026

Table 8 presents the diagnostic test results of the estimated model. The model has a high R-squared of 0.9238, indicating that approximately 92.38% of the variations in CO₂ emissions are jointly explained by the explanatory variables in the model. The F-statistic of 50.92443 (*p* = 0.0000) shows that the model is statistically significant overall. The Breusch-Godfrey serial correlation LM test has a probability value of 0.3018, which is greater than 0.05, indicating that the null hypothesis of no serial correlation cannot be rejected. Similarly, the Breusch-Pagan-Godfrey heteroskedasticity test has a probability value of 0.2818, suggesting that the residuals are homoskedastic. Overall, the diagnostic results indicate that the estimated model is statistically adequate, with no evidence of serial correlation or heteroskedasticity.

Conclusion and Recommendation

The influence of public sector expenditure on environmental quality in Nigeria was examined in this paper, with particular attention to the moderating role of corruption. The study established that public sector expenditure shows a negative and statistically significant effect on CO₂ emissions in both the short and long run. Corruption also has a negative and significant effect on CO₂ emissions, while the interaction between public sector expenditure and corruption is positive and statistically significant. However, the study recommends that government should strengthen transparency, accountability and anti-corruption mechanisms in the planning and implementation of public expenditure; public resources should be directed towards environmentally sustainable infrastructure, clean energy, pollution control and other investment-driven programmes capable of reducing carbon emissions; and appropriate monitoring and evaluation mechanisms should be established to ensure that environmental-related public expenditure is efficiently utilized. In addition, government should strengthen institutions responsible for controlling corruption and improve public financial management so that corruption does not undermine the environmental benefits of public spending.

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