



From Regulation to Resilience: How Regulatory Quality Shapes Environmental Sustainability Evidence from Nigeria

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ABSTRACT

Environmental sustainability has emerged as a significant global issue due to intensifying environmental degradation, climate change, the loss of biodiversity, pollution, and the unsustainable use of natural resources, especially in developing countries. The success of environmental governance largely depends on the effectiveness of regulatory frameworks and the mechanisms for policy implementation. This research investigates the impact of regulatory quality on environmental sustainability. The research employs a quantitative methodology utilizing secondary data sourced from the World Governance Institute database and the Nigeria Central Bank's statistical bulletin. A Nonlinear Autoregressive Distributed lag (NARDL) analysis is estimated to capture the impact of both the positive and negative effects of regulatory quality and GDP on environmental sustainability. The results indicate that enhanced regulatory quality significantly contributes to environmental sustainability through the strengthening and enforcement of environmental policies and increasing adherence to environmental standards. The study demonstrates further that both the positive and negative effects of GDP have a detrimental effect on environmental sustainability. The study concludes that strengthening regulatory quality is essential for achieving environmental sustainability. It is recommended on the basis of the findings that, Nigeria environmental policy makers should improve institutional reforms, better environmental monitoring systems as well as, stringent enforcement of environmental regulations frameworks in order to promote the country's long-term environmental sustainability.

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1.0 INTRODUCTION

Nigeria stands as the most populous country in Africa and the largest oil producer on the continent. However the nation grapples with a significant paradox, characterized by vast natural resource wealth existing alongside severe ecological degradation, institutional instability, and persistent regulatory shortcomings. From the oil-laden creeks of the Niger Delta to the increasing desertification in the north and escalating urban pollution, Nigeria's environmental issues extend beyond mere ecological concerns; they are deeply intertwined with governance challenges stemming from the inadequacies of regulatory institutions. Over the last fifty years, the inadequacies of Nigeria's environmental regulations have led to environmental pollution, adversely affecting ecosystems and human health. The shortcomings of oil producers are intrinsically linked to a broader set of institutional, legal, and political challenges that strike at the core of Nigerian federation's functionality. These governance deficiencies have consistently hindered the nation's capacity to convert environmental legislation into effective ecological results. (Chinnah 2025).

It can be argued that Nigeria's formal regulatory framework is not entirely lacking. Key agencies and instruments that constitute this regulatory framework include the Environmental Impact Assessment Act (EIA) of 1992, the National Environmental Standards and Regulations Enforcement Agency (NESREA) Act of 2007, which establishes the primary environmental enforcement body in the country, as well as, the Petroleum Industry Act (PIA) of 2021, which governs oil and gas exploration and includes provisions pertaining to climate and environmental protection. Nonetheless, there remains a considerable disparity between legal frameworks and the realities of enforcement. NESREA encounters significant obstacles, including the blatant violation of environmental laws without corresponding penalties, ineffective enforcement, corruption, and insufficient public awareness. Similarly, Nigeria's EIA framework exhibits serious concerns, such as overlapping agency functions, inadequate public participation, outdated legislation, and corporate non-compliance (Aliyu et al., 2025).

Nigeria's environmental governance embodies a complex and disturbing irony: a nation rich in natural resources and possessing an expanding array of environmental legislation, yet consistently ranked among the lowest worldwide in terms of environmental sustainability metrics. Despite several decades of regulatory efforts, environmental degradation in Nigeria persists at an alarming rate. This disjunction between regulatory intent and environmental outcomes highlights a fundamental issue that extends beyond the mere existence of legal frameworks: it constitutes a crisis of regulatory quality. The environmental governance system in Nigeria is plagued by ineffectiveness, insufficient public participation, unenforceable and non-implementable laws and policies, as well as, a weak and

uncoordinated institutional framework. This situation renders the existing environmental governance structures wholly inadequate to address the scale of the country's environmental challenges. NESREA, the primary agency responsible for environmental enforcement, confronts significant obstacles, including widespread violations of environmental laws without appropriate penalties, ineffective enforcement, corruption among regulatory personnel, and inadequate public awareness initiatives. Consequently, the regulatory framework remains largely theoretical, failing to translate statutory obligations into meaningful ecological outcomes (Nwachukwu 2024).

The issue is further exacerbated by institutional fragmentation because, there exists an overlap of responsibilities among key regulatory agencies, with legislation failing to delineate clear roles, resulting in a lack of accountability, oversight, and the necessary checks and balances to mitigate excesses. Insufficient coordination among environmental, social, and institutional subsystems within Nigeria's regulatory framework also contributes to inefficiency and environmental degradation, while institutional weaknesses and political interference further compromise regulatory effectiveness (Fagbadebo 2025). In this context, the present study investigates the ways in which regulatory quality influences environmental sustainability in Nigeria. The research therefore, seeks to provide evidence-based insights that can enhance the institutional architecture required to achieve meaningful and sustainable environmental outcomes in Nigeria.

1.1 Research Questions

This study is guided by the following research questions:

The first research question is, what is the current status of regulatory quality within Nigeria's environmental sustainability framework? The World Bank's Worldwide Governance Indicators (WGI) assess regulatory quality as one of six fundamental dimensions of governance, reflecting perceptions of a government's capacity to devise and implement effective policies and regulations across more than 200 economies from 1996 to 2024. Nigeria's consistently low scores on this index over nearly three decades prompt significant inquiries regarding the robustness and permanence of its regulatory institutions, as well as their adequacy in meeting the standards necessary to facilitate positive environmental outcomes (World Bank's WGI report, 2025).

The second research question seeks to ask, what is the correlation between economic growth and environmental sustainability in Nigeria? The resource-dependent nature of Nigeria's economy generates intrinsic conflicts between the imperatives of growth and the need for environmental protection. Insufficient governance and corrupt practices obstruct effective environmental enforcement in Nigeria, compounded by

inadequate penalties for statutory violations and a limited comprehension of environmental impact assessment processes among project proponents. This inquiry seeks to explore whether enhancing regulatory quality can alleviate the adverse environmental externalities associated with economic growth, particularly within the extractive sector (Oboro 2024).

2.0 CONCEPTS, THEORIES AND EMPIRICAL REVIEW

2.1 Conceptual insight.

At the heart of this study lies a fundamental conceptual proposition: the quality, rather than merely the existence, of regulatory institutions determines a nation's capacity to achieve environmental sustainability. This relationship has been theorised and empirically tested across various frameworks, yielding converging evidence that robust national institutions or governance systems, capable of enforcing environmental standards and norms, enhance environmental sustainability and effectively mitigate environmental degradation. Conversely, regions that are characterised by low institutional quality and weak environmental protection regulations are more susceptible to environmental damage (Si et al., 2025). Weak governance, characterised by corruption, inadequate regulatory enforcement, and a lack of the rule of law, typically impedes growth and undermines social outcomes. In contrast, governance quality which encompasses property rights, regulatory quality, and control of corruption, serves as a strong predictor of income levels, growth rates, and the effectiveness of public services. These dynamics are particularly pertinent to Nigeria, where regulatory quality has consistently fallen below the global average, remaining in the bottom third of all surveyed countries since 1996 (World Bank, WGI, 2025). High institutional quality can attract investment in low-carbon technologies, encourage the adoption of sustainable practices, and promote alignment with the Sustainable Development Goals. These outcomes rely on a stable and transparent legal framework, efficient and accountable governance, and effective enforcement of environmental regulations. This multi-channel conceptual pathway: from regulatory quality, through enforcement and compliance, to environmental outcomes, provides the theoretical foundation of this study (Atsu & Adams, 2024). However, the literature consistently highlights a significant gap between regulatory design and operational efficacy. The Petroleum Industry Act of 2021 was introduced to reform Nigeria's oil sector by consolidating legislation, enhancing transparency, and improving governance; yet, its implementation has been inconsistent. Many companies continue to flare gas despite legal prohibitions, exploiting regulatory loopholes and benefiting from weak enforcement, while penalties for non-compliance have not been uniformly applied, resulting in a permissive environment for environmental

abuse, further exacerbated by corruption and elite capture. Significant challenges in enforcing environmental laws in Nigeria include a lack of modern technology, inadequate judicial responses to environmental violations, ineffective supranational adjudicatory institutions, and a deficient political approach. Furthermore, the vast majority of international multilateral environmental treaties to which Nigeria is a signatory have yet to be domesticated, presenting an additional structural challenge to the country's legal framework for environmental governance (Ijaiya & Joseph, 2014). Within Nigeria, the detrimental impacts of oil exploration and exploitation have been attributed to weak legislation, overlapping regulatory responsibilities, poor enforcement, and an increasing lack of commitment to sustainable environmental management. This convergence of failures renders the issue of regulatory quality not merely academic, but existential for affected communities (Ogunkan, 2022). The conceptual trajectory from regulation to resilience synthesises the aforementioned strands into a coherent analytical framework. Resilience, understood as the capacity of ecological and social systems to absorb, adapt, and recover from environmental stress, is not an automatic outcome of regulatory activity. Innovation in governance is essential for accelerating the transition towards a low-carbon economy; such a transition necessitates policies that are adaptive to environmental change and efficient in managing natural resources sustainably. Institutional resilience refers to the ability of institutions to adapt and respond to environmental changes while ensuring the long-term sustainability of policies (Mahé & Martel, 2023). Applied to Nigeria, this conceptual bridge reveals three critical linkages: firstly, regulatory quality influences the stringency and credibility of environmental rules; secondly, institutional capacity and enforcement determine whether these rules translate into compliance; and thirdly, compliance and accountability collectively ascertain whether environmental resilience is achievable. The influence of institutional quality on environmental sustainability operates through multiple moderating channels, including economic growth, foreign direct investment, and renewable energy adoption, all of which depend on the quality of the governance environment to yield net positive environmental effects. Where, as in Nigeria, these governance preconditions are weak, even substantial economic activity or formal regulatory reform may fail to produce the ecological outcomes that the concept of resilience necessitates.

2.2 Theoretical Insight

The connection between regulatory status and tangible sustainability requires diversified theoretical traditions, each contributing a different glass through which the Nigerian knowledge maybe checked. This review synthesizes four principal hypothetical frameworks that involve; New Institutional Economics, the Porter Hypothesis, the Pollution Haven Hypothesis, and the

Environmental Kuznets Curve. This is due to the fact that no one concept is sufficient for expertise Nigeria's supervisory-sustainability problem.

New Institutional Economics (NIE)

The foundational theoretical framework for this study is New Institutional Economics (NIE), primarily developed by Douglass C. North (1993). NIE diverges from neoclassical economics by positioning institutions such as, the formal rules, informal norms, and enforcement mechanisms that govern human interaction as central to economic and developmental outcomes. Within North's framework, institutions are not merely contextual factors; rather, they serve as the principal determinants of whether economies achieve efficient development or remain ensnared in suboptimal equilibria (Davis & Boianovsky, 2024). When applied to environmental governance, NIE offers a theoretical foundation for comprehending the persistent failure of formal environmental regulations in Nigeria to yield the desired outcomes. Governance establishes the rules that dictate long-term growth; institutional arrangements that promote widespread access to opportunities, uphold the rule of law, and prevent the concentration of unchecked power foster investment, innovation, and entrepreneurship. Furthermore, accountability through transparent budgeting, performance monitoring, and citizen engagement enhances the effectiveness of public services. In the absence of these institutional prerequisites, as observed in Nigeria's environmental governance sector, formal rules become symbolic rather than binding, creating an illusion of regulatory order that conceals underlying institutional dysfunction (World Bank WGI, 2025). NIE also emphasises the concept of path dependence, which posits that historical institutional choices constrain future options. Nigeria's colonial legacy, its petro-state political economy, and its extensive history of regulatory capture have generated institutional path dependencies that render meaningful reform structurally challenging. The quality of institutions, including governance structures, regulatory frameworks, and legislation shapes the enabling environment for sustainability, while simultaneously influencing investor confidence, risk perceptions, and sustainable business practices.

The Porter Hypothesis (PH)

The Porter Hypothesis, introduced by Michael Porter and Claas van der Linde in 1995, presents a more favourable theoretical perspective on the interaction between regulation and the environment. This hypothesis depose that strong environmental rules can boost efficiency and stimulate innovations that enhance business competitiveness. It proposes that strict regulations lead to the development and adoption of cleaner technologies and improvements in environmental quality, referred to as the "innovation effect," resulting in more efficient production methods and products (Ambec et al, 2013).

The hypothesis can be understood in three levels of increasing level. The "narrow" interpretation suggests that flexible regulations enhance the motivation for companies to innovate; the "weak" interpretation posits that environmental regulations will catalyze specific types of innovations; and the "strong" interpretation asserts that the advantages gained from innovations driven by adhering to environmental regulations will outweigh the expenses incurred for regulatory compliance. The majority of empirical findings back the weak interpretation since regulations indeed encourage environmental innovation. Evidence supporting the strong interpretation remains inconsistent, especially in developing nations where the capacity to adopt technology is limited (Zhang et al, 2024).

In the context of Nigeria, the Porter Hypothesis poses a significant inquiry: can enhanced regulatory quality foster green innovation and improve efficiency, despite operating within a resource-dependent and low-technology economy? The perspective which is centered on compliance costs argues that, environmental regulation undermines the optimal choices made by businesses due to increased short-term expenses. Equally, the Porter Hypothesis maintains that suitable environmental regulations foster innovation in businesses and that the benefits derived from such innovations might even surpass the costs associated with regulatory compliance, thus enhancing companies' profitability. However, Nigeria's existing regulatory framework, characterized by inadequate enforcement and widespread corruption, fails to establish an environment conducive to either compliance or innovation-driven advantages, indicating that the country is still distant from realizing the potential benefits outlined by the Porter Hypothesis (Mu et al, 2022).

The Pollution Haven Hypothesis (PHH)

The Pollution Haven Hypothesis (PHH) presents an alternative theoretical viewpoint that is fundamentally negative in nature. According to the PHH, companies focused on maximizing profits and involved in pollution will shift their production to areas with less stringent environmental regulations, leading to reduced compliance expenses. This shift results in the concentration of harmful emissions and industrial pollution in these areas, described as "havens." The theory suggests that countries that are still developing, characterized by poor regulatory standards, will disproportionately draw in industries that are heavy polluters, creating a situation where regulatory weaknesses become self-perpetuating (Muhammad 2022).

Fierce competition for foreign investment could prompt a "race to the bottom" regarding environmental standards, with businesses preferring to operate in nations that have lenient regulations to minimize costs associated with pollution control. One primary reason developing nations hesitate to implement more stringent environmental regulations is due to the influence of the

pollution haven effect. Nigeria serves as a notable example of how this effect operates. The long-standing oil pollution in the Niger Delta, ongoing gas flaring by international companies, and the Nigerian government's historically lenient approach towards oil corporations exemplify the structural patterns anticipated by the PHH (Wen et al, 2022).

The Niger Delta has experienced extensive oil extraction activities, with many multinational companies at work in the area. However, this has resulted in significant environmental harm, public health issues, and social tensions, all stemming from the operations of these companies, a situation that is further aggravated by frail environmental laws and poor enforcement. Therefore, the PHH offers a theoretical framework to comprehend how Nigeria's inadequate regulatory quality has rendered it particularly susceptible to the offloading of environmental costs by influential business entities (Wen et al, 2022).

The Environmental Kuznets Curve (EKC)

The Environmental Kuznets Curve hypothesis offers a broad theoretical framework that explains the dynamics of regulatory quality and sustainability over time. The EKC serves as a conceptual framework indicating that a nation's pollution levels increase in tandem with its growth and industrial development until a certain point, after which levels begin to decrease as the nation utilizes its enhanced wealth to lower pollutant emissions. Importantly, this theory highlights that the quality of institutions is a significant factor influencing both the peak pollution levels and the speed at which a nation can reach that decline (Levinson & Scott-Taylor, 2008).

The quality of regulations and institutions impacts environmental outcomes because more effective institutional arrangements can improve environmental standards alongside economic progress. Furthermore, policies that prioritize environmental protection and strategies focused on low-carbon growth can enable nations to break free from a "pollution trap" and avert ecological deterioration. Nigeria's situation concerning the EKC is particularly alarming: existing empirical data supports the inverted U-shape model, yet the critical turning point has not been achieved. Additionally, revenues from oil are contributing to worsening environmental pollution, while the effects of urbanization and income growth on the environment remain unclear. This suggests that without intentional enhancements in regulatory quality, Nigeria's pollution trajectory will persist in its upward trend well before any corrections driven by market forces can occur (Uwazie et al, 2025).

Each of the four theories discussed above provides insight into the connection between regulatory quality and environmental sustainability. When considered collectively, they offer a comprehensive and somewhat alarming theoretical framework for Nigeria. The New Institutional Economics (NIE) sheds light on why regulatory institutions face structural and historical

failures; the Porter Hypothesis describes the potential achievements of effective regulation; the Porter Hypothesis with respect to the environment emphasizes the structural factors that perpetuate regulatory inadequacies; and the EKC positions Nigeria within a development pathway that could be expedited through institutional reforms. This amalgamation shapes the conceptual foundation of the current research: regulatory quality is not merely a standalone governance element but serves as the essential institutional framework that influences environmental legislation, market motivations, and ecological results, and in the case of Nigeria, these processes are systematically distorted (Aydin et al, 2024).

2.3 Empirical Review

An increasing volume of empirical studies consistently supports the notion that the quality of institutions and regulations plays a critical role in influencing environmental results. Research investigating governance in resource-abundant African nations and various other areas indicates that effective governance substantially reduces CO₂ emissions. Additionally, the relationship between institutional quality, renewable energy, and the use of fossil fuels illustrates the beneficial environmental impacts generated by strong governance structures (Charles et al, 2025).

Ibekilo et al. (2023) conducted a study utilizing panel data from 33 African countries spanning 1996 to 2020, which specifically examines the influence of regulatory quality on environmental sustainability. The findings reveal that urbanization contributes to increased environmental pollution, energy use heightens ecological degradation, and regulatory quality can partially alleviate pollution in Africa through pathways related to urbanization and energy consumption. This establishes a moderating effect in which the interaction of regulatory quality with urban growth and energy utilization leads to diminished environmental pollution. This outcome holds significant relevance for Nigeria, a nation experiencing rapid urban growth and high energy usage, where the necessary regulatory mediation is critically absent.

On a global scale, studies focusing on governance quality and sustainable development analyze data from 48 countries in Sub-Saharan Africa from 2010 to 2022, utilizing the Generalised Method of Moments (GMM) approach. These studies emphasize that indicators of governance serve as strong predictors of sustainability outcomes throughout the Sustainable Development Goals framework. This confirms that the relationship between regulatory quality and sustainability is not confined to a specific region but reflects a structural logic of institutions applicable to Nigeria (Adebayo et al, 2025).

The empirical literature specific to Nigeria offers the most direct examination of the link between regulatory quality and environmental sustainability, despite having mixed and methodologically debated findings. One of the most relevant studies is conducted

by Maduka et al. (2022), who investigate the connection between economic growth and carbon dioxide levels, along with the moderating role of institutional quality in Nigeria from 1990 to 2020. This study employs both long-run and short-run dynamic ARDL regression, quantile regression, and Granger causality tests. Key variables considered include CO₂ emissions per capita, GDP per capita, capital investment, control over corruption, and regulatory quality. The findings reveal a notable cointegration between CO₂ emissions and economic growth within Nigeria, establishing an N-shaped relationship between CO₂ emissions and economic growth in both the long term and short term, challenging the inverted U-shape suggested by the Environmental Kuznets Curve hypothesis.

Importantly, by examining the moderating influence of institutional quality, the research utilizes ARDL and quantile regression methods to reject the EKC hypothesis within Nigeria, instead uncovering an N-shaped association between CO₂ emissions and economic development both in the short term and the long term. This outcome suggests that Nigeria's emissions path fails to naturally adjust to higher income levels, indicating that, without intentional institutional actions, the nation might experience repeated peaks in emissions rather than reach a single sustainable threshold (Espoir, et al, 2023).

Additional empirical investigations analyzing environmental degradation pathways and economic growth in Nigeria from 1990 to 2023 indicate that NESREA and similar agencies must enhance environmental procedures and foster green foreign investments to mitigate the adverse environmental impacts associated with economic progression. This reflects an implicit recognition that the current quality of regulation falls short in addressing the environmental challenges stemming from Nigeria's growth pattern (Oniore et al 2025).

Regarding the relationship between corruption and the environment, data from West African nations, including Nigeria, collected from 1990 to 2020 through the PMG-ARDL panel approach reveals that GDP per capita has a significant positive impact on CO₂ emissions, failing to confirm the Kuznets curve. In this context, renewable energy usage and corruption control emerge as crucial elements in the pursuit of environmental quality, with foreign direct investment supporting the pollution haven theory by diminishing environmental standards over time. This evidence establishes a direct connection between inadequate anti-corruption governance and deteriorating environmental sustainability results (Nkemdilim et al, 2023).

Besides macroeconomic modeling, sector-specific empirical research highlights the practical ramifications of Nigeria's shortcomings in regulatory quality within its primary extractive sector. Insights from the Nigerian oil and gas sector expose ineffective governance systems that do not ensure accountability among political elites and state institutions. Noteworthy incidents, such as the OPL 245 scandal, illustrate how

institutional capture and elite corruption facilitate the regular evasion of regulatory responsibilities amounting to billions of dollars (Agbonifo 2024). An empirical review of oil spill incidents from 2021 to 2024 across six oil-producing regions, where Rivers, Bayelsa, and Delta are the most severely impacted, reveals extensive contamination of soil, water, and air, the decline of biodiversity, and detrimental health impacts caused by regulatory failures. Numerous companies persist in gas flaring despite a legal ban due to exploiting regulatory vulnerabilities and profiting from weak enforcement, while penalties for non-compliance under the Petroleum Industry Act have not been applied uniformly, fostering an environment conducive to environmental degradation exacerbated by corruption and elite exploitation (Omokaro et al, 2025).

These sector-specific insights correlate with Nigeria's overall governance rankings. The amount of fossil CO₂ emissions in Nigeria reached 131.9 million tons in 2024, reflecting a 4.8% rise compared to 2023, indicating a direction that strays from Nigeria's declared NDC pledge to reduce emissions to 20% below business-as-usual levels by 2030. This discrepancy between regulatory commitments and emissions trends represents the precise implementation gap highlighted in the empirical literature, attributed to deficiencies in regulatory quality (Fransen et al, 2023). A supporting set of panel data findings from sub-Saharan Africa enhances the conclusions drawn from Nigeria at a broader regional scope. Research that investigates the links among institutional quality indicators and CO₂ emissions in sub-Saharan African nations from 2000 to 2021 employs the CS-ARDL method and finds considerable long-term associations between these quality measures and carbon emissions. This establishes a cointegration, demonstrating that the relationship between institutional quality and emissions is strong across various African economies (Sitara et al, 2022).

Utilizing the two-step system GMM panel approach with data from 43 nations in sub-Saharan Africa, a study by Amuakwa-Mensah & Adom, (2017) reveals that energy inefficiency negatively affects environmental conditions. However, the quality of institutional frameworks can mitigate this adverse effect, as nations with strong institutional frameworks are likely to achieve better environmental sustainability compared to those with weak institutions. Therefore, Nigeria's consistently low institutional ratings not only indicate an increase in pollution but also suggest a diminished ability to take advantage of energy changes and green investments that could enhance environmental results.

2.4 Gaps in the Empirical Literature

The reviewed empirical literature highlights multiple significant gaps that this research aims to fill. Firstly, a majority of studies centered on Nigeria concentrate on the relationship between macroeconomic factors and growth, without breaking down the precise ways in which regulatory quality, as separate from broader institutional

quality, influences environmental results (Global Forest Watch, 2025). Additionally, investigations that include regulatory quality as a moderating factor often report either statistically non-significant or unclear immediate impacts within Nigeria, emphasizing the need for more detailed, empirical studies. Furthermore, the relationship between the capacity for regulatory enforcement, and the results of environmental compliance has not been extensively investigated in Nigeria, even though it is crucial to understanding the pathway of regulatory resilience. Consequently, this study provides new empirical insights that address these deficiencies, positioning regulatory quality as both a direct factor and a structural intermediary in the pursuit of environmental sustainability in Nigeria.

3.0 MATERIALS AND METHODS

3.1 Research Design

The philosophical basis for this research is rooted in, is the positivist framework. This perspective prioritizes impartiality, repeatability, and utilizes statistical methods for hypothesis testing; scholars working within this framework generally adopt systematic approaches, such as longitudinal research, which aid in gathering quantifiable information aimed at yielding trustworthy and valid findings that can be applied to broader demographics. Since this research intends to determine causal and long-term links between measurable governance factors and environmental results in Nigeria, positivism serves as the suitable epistemological foundation (Irwan 2024).

3.2 Estimation Strategy.

The estimation strategy utilized in this research is the Non-linear Autoregressive Distributed Lag (NARDL)

$$\Delta SUST_t = \beta_0 + \sum_{i=1}^p \beta_1 \Delta SUST_{t-i} + (\sum_{i=1}^p \beta_2 \Delta RQI_{t-i}^+ + \sum_{i=1}^p \beta_3 \Delta RQI_{t-i}^-) + (\sum_{i=1}^p \beta_4 \Delta GDP_{t-i}^+ + \sum_{i=1}^p \beta_5 \Delta GDP_{t-i}^-)$$

3.4 Definition of variables

Environmental sustainability (SUST): refers to the responsible use, management, and conservation of natural resources and ecosystems in a way that meets the current needs without eroding the capacity of future generations to meet their own needs. It involves maintaining ecological balance, preserving biodiversity, reducing environmental degradation, and ensuring the long-term resilience of natural systems. Primary forest loss is an appropriate proxy for environmental sustainability because it captures multiple dimensions of environmental quality, including biodiversity conservation, ecosystem integrity, carbon storage, and natural resource preservation. A reduction in primary forest loss indicates improved environmental sustainability, whereas increasing forest loss reflects

model, as proposed by Pesaran, Shin, & Smith (2001). Several methodologically valid reasons for choosing the NARDL method abounds. A primary benefit of the NARDL model is its capacity to accommodate regressors with different orders of integration, specifically $I(0)$ or $I(1)$, which traditional cointegration assessments do not allow, rendering it especially appropriate for governance and environmental metrics that do not conform to a consistent integration order (Chung et al, 2019).

3.3 Method of data collection and the model

This study employs time series data, obtained from the World Bank's World Development Indicators database (2024), as well as, the Nigeria's Central Bank statistical bulletin (2025). The data span the years from 2005 to 2024.

The general model for the Non-linear Autoregressive Distributed Lag (NARDL) is presented below, following the work of Obomeghie & Umoru (2024).

$$\begin{aligned} SUST &= \beta_0 + \beta_1 GDP + \beta_2 RQI + u_t \\ RQI_t^+ &= \sum_{j=1}^t \Delta RQI_j^+ = \sum_{j=1}^t \max(\Delta RQI_{j,o}) \\ RQI_t^- &= \sum_{j=1}^t \Delta RQI_j^- = \sum_{j=1}^t \max(\Delta RQI_{j,o}) \\ GDP_t^+ &= \sum_{j=1}^t \Delta GDP_j^+ = \sum_{j=1}^t \max(\Delta GDP_{j,o}) \\ GDP_t^- &= \sum_{j=1}^t \Delta GDP_j^- = \sum_{j=1}^t \max(\Delta GDP_{j,o}) \end{aligned}$$

The general NARDL (p, q, r, s) model where p, q, r, s , are lag orders can be written as;

environmental degradation and unsustainable resource use. (UNEP, 2021)

Gross Domestic Product (GDP): is the total monetary value of all final goods and services produced within a country's borders during a specified period, usually a year. GDP is the most widely used indicator of economic performance and it reflects the size and growth of an economy. It is expected that GDP exerts either a positive or negative relationship with sustainability.

Regulatory quality (RQI): refers to the ability of a government to formulate, implement, and put in force sound regulations and policies that promote economic and social development while ensuring effective governance and institutional performance. It reflects the extent to which regulations are transparent, predictable, efficient, and supportive of public welfare objectives

3.5 Justification of the methodology

The quantitative *ex-post facto* design, anchored in positivist philosophy and operationalized through the NARDL framework is used in this because, it is consistent with the dominant methodological tradition in the empirical literature on governance and environmental sustainability in Africa; it exploits the richest available data on Nigeria's regulatory and environmental trajectory; and it generates findings with direct, policy-

actionable implications for how regulatory reform can accelerate Nigeria's transition from regulatory dysfunction to ecological resilience.

4.0 RESULTS AND DISCUSSION

The descriptive statistics of our analysis is presented below in table 1.

Table 1. Descriptive statistics.

	SUST	GDP	RQI
Mean	8.855000	1.269623	-0.891500
Median	8.650000	2.037751	-0.900000
Maximum	17.00000	5.067183	-0.630000
Minimum	1.900000	-8.342423	-0.990000
Std. Dev.	4.575504	3.271980	0.081388
Skewness	0.100086	-1.375549	1.531841
Kurtosis	1.751748	4.843733	6.317848
Jarque-Bera	1.331835	9.139914	16.99522
Probability	0.513802	0.010358	0.000204
Sum	177.1000	25.39246	-17.83000
Sum Sq. Dev.	397.7695	203.4112	0.125855
Observations	20	20	20

Source; Author's computation from e-views output

From table 1 above, it can be seen that sustainability (SUST) has the highest mean while regulatory quality (RQI) has the lowest mean with 8.855000 and -0.891500 respectively. As well, SUST has the highest standard deviation while RQI again has the lowest standard deviation with 4.575504 and 0.081388 respectively. This indicates that the values for economic sustainability vary

widely across the data set. It also means that, there is a large amount of fluctuation in economic sustainability among the observations. On the other hand, regulatory quality with the lowest standard deviation means that, the values for the regulatory quality is relatively stable and consistent across the data set.

Table 2. Cointegrations test

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.741459	30.10425	24.27596	0.0083
At most 1	0.167347	5.755637	12.32090	0.4664
At most 2	0.127697	2.459142	4.129906	0.1380
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.741459	24.34861	17.79730	0.0045
At most 1	0.167347	3.296495	11.22480	0.7412
At most 2	0.127697	2.459142	4.129906	0.1380

Source; Author's computation from e-views output

The cointegration test is represented in table 2 above. From the table it can be seen that both the Trace test and the Max=Eigen values of 30.10425 and 24.34861 are

greater than the 5% critical values of both 24.27596 and 17.79730 respectively, clearly indicating a long-run relationship between the variables.

Table 3. Stationarity test.

Variable	Order	ADF value	Prob	Conclusion
SUST	I (1)	-5.264431	0.0005	Stationary
GDP	I (0)	-4.498124	0.0030	Stationary
RQI	I (1)	-3.594639	0.0157	Stationary

Source; Author's computation from e-views output

From table 3, it can be observed that all the variables used in the analysis are stationary at first difference except GDP which is stationary at levels. If values are stationary, it means that they do not change or fluctuate over time. In statistical and analytical contexts, stationarity has specific implications for empirical analysis which includes;

Predictability and stability; Since values remain constant over time, future values can be reliably predicted based on past data. This stability simplifies modeling and forecasting because the underlying data distribution does not change.

Simplified analysis: Many statistical techniques, such as regression analysis and time series modeling, require stationarity to produce valid results. Non-stationary data can lead to spurious correlations, so stationarity ensures more accurate and meaningful analysis.

No trends or cycles; Stationary data lack trends, seasonal effects or cycles, meaning that the mean and variance are constant. This implies a steady environment without significant shifts or long-term changes.

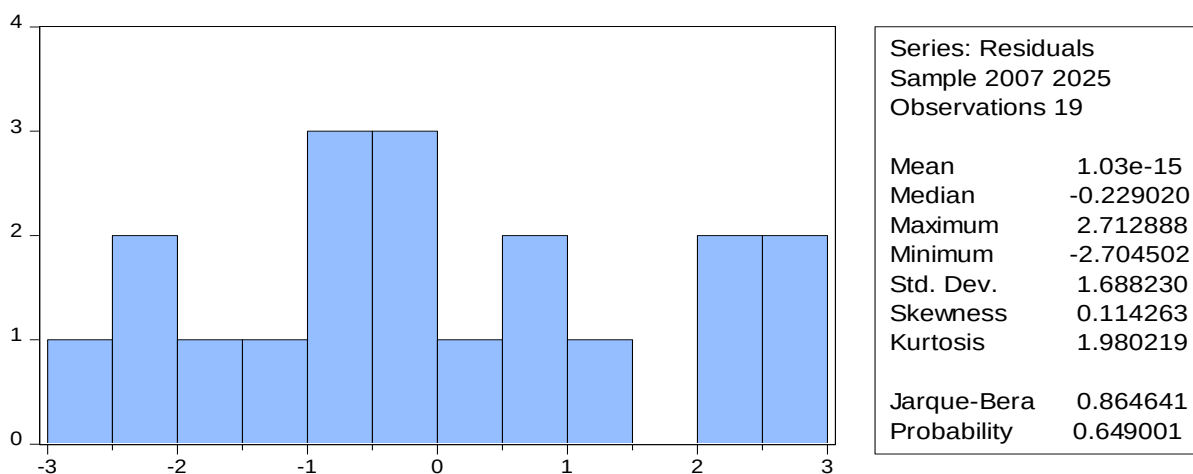
Table 4. Serial Correlation

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	3.453647	Prob. F(2,9)	0.0771
Obs*R-squared	8.250214	Prob. Chi-Square(2)	0.0162

Source: Author's computation from e-views output

The Breusch–Godfrey serial correlation LM test in table 4 above indicates an F-statistic of 3.453647 ($p = 0.0771$), suggests that the null hypothesis of no serial correlation cannot be rejected at the 5% level. If an OLS analysis shows no serial correlation (autocorrelation) in the

residuals, it means that the errors are independent across observations or time periods. This is a desirable result because it indicates that one of the key assumptions of the classical linear regression model has been satisfied.

**Figure 1. Normality test**

From figure 1 which depicts the normality test, the Jarque-Bera value of 0.8646412 with a corresponding probability of 0.649001, indicates that the variables used are normally distributed. The implications of normal distribution in econometric analysis include;

Validity of statistical inference; Many inferential statistics, such as t-tests and F-tests, rely on the assumption of normality of the error terms or variables. Normality ensures that the sampling distribution of estimators is

approximately normal, especially in large samples, enabling valid hypothesis testing and confidence interval construction.

Efficiency and unbiasedness of estimators; Under the assumption of normally distributed variables, the Ordinary Least Squares (OLS) estimators are not only unbiased but also the Best Linear Unbiased Estimators (BLUE). It also helps in verifying the assumptions needed for estimator optimality.

Simplification of model diagnostics; Normality facilitates the use of residual analysis, QQ plots, and other diagnostic tools to assess the goodness of fit. It

simplifies the detection of outliers and influential data points.

Applicability of parametric tests: Many parametric tests assume normality; if variables are normally distributed, these tests are more reliable. This includes tests for coefficients, joint hypotheses, and model specifications.

In conclusion, if variables are normally distributed, it generally enhances the validity and reliability of statistical inference in econometric models, simplifies diagnostics, and supports the use of parametric tests.

Table 5. The NARDL result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Short run equation				
C	3.370016	1.916379	1.758533	0.1064
SUST(-1)*	-1.076662	0.252386	-4.265939	0.0013
GDP_POS**	-0.925132	0.387989	-2.384429	0.0362
GDP_NEG(-1)	-0.749102	0.407008	-1.840509	0.0928
RQI_POS(-1)	27.33362	11.95549	2.286282	0.0431
RQI_NEG**	-44.95191	27.81883	-1.615881	0.1344
D(GDP_NEG)	0.089825	0.273398	0.328552	0.7487
D(RQI_POS)	-6.454633	12.42153	-0.519633	0.6136
Long run equation				
GDP_POS	-0.859260	0.306215	-2.806061	0.0171
GDP_NEG	-0.695764	0.306455	-2.270363	0.0443
RQI_POS	25.38738	13.22022	1.920345	0.0811
RQI_NEG	-41.75119	22.97925	-1.816908	0.0965
C	3.130060	1.737811	1.801151	0.0991

Source: Author's computation from e-views output

Interpretations

The results reveal that both positive and negative GDP shocks exert negative effects on environmental sustainability. Specifically, a positive GDP shock (GDP_POS) with a coefficient of -0.859260 ($p = 0.0171$), indicates that economic expansion significantly reduces environmental sustainability. Similarly, a negative GDP shock (GDP_NEG) with a coefficient of -0.695764 ($p = 0.0443$), suggest that economic contraction also significantly reduces environmental sustainability. The larger absolute magnitude of the positive shock coefficient implies that economic growth has a stronger detrimental effect on environmental sustainability than economic decline. These findings indicate an asymmetric relationship between GDP and environmental sustainability, whereby expansions and contractions in economic activity affect environmental outcomes differently (Pathirana 2024).

With respect to regulatory quality, the results indicate that positive changes in regulatory quality (RQI_POS) exert a positive effect on environmental sustainability, with a coefficient of 25.38738 ($p = 0.0811$). This suggests that improvements in regulatory quality

contribute to enhanced environmental sustainability, although the effect is statistically significant only at the 10% level. Conversely, negative changes in regulatory quality (RQI_NEG) with a coefficient of -41.75119 ($p = 0.0965$), indicates that deteriorations in regulatory quality significantly reduce environmental sustainability at the 10% significance level. The larger absolute magnitude of the negative coefficient suggests that environmental sustainability is more adversely affected by declines in regulatory quality than it is improved by equivalent enhancements in regulatory quality. These findings provide evidence of a potentially asymmetric relationship between regulatory quality and environmental sustainability (Teixeira et al, 2025).

5.0 CONCLUSION AND RECOMMENDATIONS

Both positive and negative shocks to GDP have a considerable detrimental impact on environmental sustainability, indicating that fluctuations in GDP (whether upward or downward) tend to lead to a decrease in environmental sustainability. Moreover, the coefficient for the positive GDP shock being larger

suggests that growth in the economy has a more substantial negative influence on environmental sustainability compared to economic downturns. Consequently, the findings imply that the effects of GDP on environmental sustainability are asymmetric. This observation aligns with similar research conducted by Chun et al, (2025).

Additionally, it is inferred that the quality of regulations significantly influences environmental sustainability. Enhancing regulatory quality typically benefits environmental sustainability, while a decline in regulatory standards considerably harms it. Though these effects are only statistically significant at the 10% threshold, the results imply that it is crucial to sustain and reinforce regulatory frameworks to achieve environmentally sustainable outcomes, reflecting findings from Costantiello & Leogrande, (2024).

Based on the findings from this research, which demonstrate that both positive and negative GDP fluctuations significantly harm environmental sustainability, it is advised that policymakers implement a cohesive development strategy that fosters economic growth alongside the protection of environmental resources. Special focus should be placed on bolstering environmental regulations, facilitating the adoption of renewable energy, promoting sustainable industrial practices, and maintaining efforts to protect the environment during times of economic growth and contraction. Such initiatives are vital for realizing sustainable development in the long run.

The study also advocates for the enhancement of regulatory quality through improved institutional efficiency, consistency in policies, transparency, and rigorous enforcement of environmental regulations. Given that a decline in regulatory quality negatively impacts environmental sustainability more severely than the benefits arising from regulatory enhancements, it is essential for policymakers to prioritize the prevention of institutional deterioration while also strengthening governance mechanisms that foster sustainable environmental management. Moreover, objectives related to environmental sustainability should be incorporated into economic growth strategies to ensure that development proceeds without compromising environmental integrity.

Conflict of Interest

The authors declare no conflict of interest.

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