

Firm Characteristics, Corporate Governance, and Environmental Sustainability Disclosure in Manufacturing Firms in Nigeria (2014–2025)

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Abstract- Environmental sustainability disclosure (ESD) is acknowledged globally as an important mechanism for enhancing corporate transparency and environmental accountability. However, evidence on its determinants among manufacturing firms in emerging economies remains fragmented and inconclusive. This study examines the influence of firm characteristics and corporate governance on ESD of listed manufacturing firms in Nigeria from 2014 to 2025. ESD was measured using a composite index constructed from five Global Reporting Initiative (GRI 300) environmental disclosure dimensions through principal component analysis (PCA). The data were analyzed using the panel autoregressive distributed lag (Panel ARDL) model estimated through the Pooled Mean Group (PMG) estimator to capture both the short-run and long-run relationships. The results reveal that firm size, firm age, board size, board independence, and board gender diversity positively and significantly influence ESD in the long run, while the error correction term confirms a stable long-run equilibrium relationship. This study contributes to the literature by integrating firm characteristics and corporate governance within a unified framework, constructing an objective PCA-based environmental disclosure index, and applying a dynamic Panel ARDL-PMG approach. The results provide important implications for regulators, corporate boards, and policymakers seeking to strengthen environmental reporting practices and sustainable industrial development in Nigeria.

Keywords: Environmental Sustainability Disclosure, Firm Characteristics, Corporate Governance, Manufacturing Firms, Panel ARDL-PMG, Principal Component Analysis, Nigeria.

I. INTRODUCTION

Environmental sustainability disclosure (ESD) has become a central component of contemporary

corporate reporting, reflecting growing global expectations for corporate accountability and sustainable development. Escalating climate change, biodiversity loss, resource depletion, and environmental degradation have intensified pressure on firms to disclose credible information regarding their environmental impacts, mitigation strategies, and sustainability performance (Udo et al., 2025; Enemuo et al., 2025).

Consequently, environmental reporting has evolved beyond a voluntary corporate social responsibility initiative into a strategic governance mechanism through which firms reduce information asymmetry, enhance stakeholder confidence, strengthen organizational legitimacy, and create long-term value (Ukpe & Michael, 2019; Ukpogong & Ukpe, 2023). This transition has been reinforced by international reporting frameworks such as the Global Reporting Initiative (GRI), the Task Force on Climate-related Financial Disclosures (TCFD), and the International Sustainability Standards Board (ISSB), which encourage firms to disclose standardized information on greenhouse gas emissions, energy consumption, pollution prevention, environmental expenditure, waste management, and climate-related risks (Canice et al., 2026; Samuel et al., 2021). Consequently, ESD has become an important determinant of corporate reputation, investment decisions, regulatory compliance, and sustainable value creation (Abuaja & Ukpogong, 2022).

Eyo and Ukpe (2016), Amos et al. (2018), and others have revealed that the importance of ESD is particularly evident within the manufacturing sector, given the sector's contribution to greenhouse gas emissions (GHGs), industrial waste, water pollution,

and natural resource depletion. These environmental externalities, according to Udo et al. (2026), expose agricultural and manufacturing firms to stringent environmental regulatory scrutiny and stakeholder pressure on environmental sustainability. Consequently, Essien et al. (2023) revealed that ESD enables investors, regulators, host communities, and other stakeholders to monitor firms' commitment to sustainable production.

Despite the increasing institutionalization of sustainability reporting, considerable differences remain in the quality and extent of environmental disclosure across countries. Firms operating in developed economies generally provide more comprehensive environmental reports because of stronger regulatory enforcement, mature capital markets, and greater stakeholder activism. In contrast, firms in emerging economies continue to exhibit inconsistent disclosure practices owing to institutional weaknesses, limited regulatory enforcement, resource constraints, and weak governance systems (Zayol et al., 2021; Ofoegbu & Megbulu, 2016). Consequently, identifying the organizational and governance factors that explain variations in environmental sustainability disclosure has become an important research issue.

Nigeria provides an appropriate context for this investigation because manufacturing remains central to the country's industrialization and economic diversification agenda while simultaneously contributing significantly to environmental pollution, greenhouse gas emissions, and resource depletion. To improve corporate accountability, regulatory institutions, including the Securities and Exchange Commission (SEC), the Financial Reporting Council of Nigeria (FRCN), and the Nigerian Exchange Group (NGX), have introduced sustainability reporting guidelines and corporate governance reforms aimed at strengthening environmental disclosure.

However, (Udo et al. 2025; Abuaja & Ukpong, 2022) revealed that improvements in the regulatory framework have not been matched by corresponding improvements in corporate ESD. Extant studies in Nigeria attribute lack of adequate ESD to voluntary,

selective, and descriptive reporting on environmental performance, emissions reduction, environmental expenditure, and resource efficiency (Ofoegbu & Megbulu, 2016; Essien 2018; Ruhana & Hidayah, 2019; Zayol et al., 2021). Weak regulatory enforcement, high compliance costs, and limited environmental accountability continue to reduce firms' incentives to provide comprehensive sustainability disclosures, thereby limiting transparency and informed stakeholder decision-making.

The existing literature also presents important conceptual, contextual, and methodological limitations. Conceptually, previous studies have generally examined firm characteristics and corporate governance separately, despite evidence that environmental disclosure is jointly influenced by organizational capacity and governance quality (Amos et al., 2018; Seow, 2024). Moreover, stakeholder, legitimacy, agency, and resource dependence theories have frequently been applied independently, providing only partial explanations of firms' environmental disclosure behavior.

Contextually, most Nigerian studies have concentrated on oil and gas companies, financial institutions, or mixed-industry samples, with relatively limited attention devoted to manufacturing firms despite their substantial environmental footprint (Ayange et al., 2021). Methodologically, prior studies have relied predominantly on static panel models, relatively short observation periods, and equally weighted disclosure indices that emphasize disclosure quantity rather than disclosure quality and multidimensionality (Ghosh et al., 2023). Consequently, existing evidence provides only a partial understanding of the dynamic relationship between firm characteristics, corporate governance, and environmental sustainability disclosure.

This study addresses these limitations by integrating stakeholder theory, legitimacy theory, agency theory, and resource dependence theory into a unified analytical framework to explain environmental sustainability disclosure. Empirically, it investigates listed manufacturing firms in Nigeria over the period 2014–2024, thereby capturing important regulatory

developments and changes in sustainability reporting practices.

Distinct from extant studies, ESD is measured using a composite index constructed from five environmental reporting dimensions, such as energy consumption and efficiency, greenhouse gas (GHG) emissions, environmental expenditure and investments, environmental training and awareness programmes, and environmental risk management. Based on the Global Reporting Initiative (GRI 300 Environmental Standards) and weighted objectively through principal component analysis (PCA).

Furthermore, the study employs the Panel Autoregressive Distributed Lag (Panel ARDL) model estimated using the Pooled Mean Group (PMG) estimator to distinguish between short-run and long-run effects while accounting for firm heterogeneity and dynamic adjustment. Collectively, these theoretical, methodological, and empirical innovations provide more robust evidence on the determinants of environmental sustainability disclosure and offer policy insights for strengthening corporate governance, environmental accountability, and sustainable industrial development in Nigeria.

II. LITERATURE REVIEW

Environmental Sustainability Disclosure

Environmental sustainability disclosure (ESD) refers to the systematic reporting of information relating to a firm's environmental policies, practices, risks, and performance to stakeholders. It enables organizations to communicate their environmental impacts, resource utilization, pollution prevention initiatives, climate-related risks, and sustainability performance, thereby enhancing corporate transparency, accountability, and sustainable development (Omotayo & Idris, 2025; Chinedu, 2024). Increasing concerns over climate change (Abuja & Ukpong, 2022), environmental degradation (Udo et al 2025; Zayol et al., 2021), financial structure and risk factor in audit fees (Thomas & Chistopher 2025; Edet et al 2025) and stakeholder expectations (Olayemi & Onuoha, 2023) have transformed ESD from a voluntary corporate social responsibility initiative into a strategic component of corporate reporting that

strengthens organizational legitimacy, reduces information asymmetry, and supports long-term value creation.

The growing importance of ESD has been reinforced by internationally recognized reporting frameworks, particularly the Global Reporting Initiative (GRI), the Task Force on Climate-related Financial Disclosures (TCFD), and the International Sustainability Standards Board (ISSB), which promote standardized and comparable environmental reporting. Despite these developments, environmental disclosure practices remain inconsistent across many developing economies, including Nigeria, where weak regulatory enforcement, resource constraints, and variations in corporate governance continue to influence the quality and extent of environmental reporting (Abuja & Ukpong, 2022). Consequently, considerable differences persist in firms' environmental disclosure practices.

The measurement of ESD has evolved considerably. Earlier studies predominantly employed content analysis and equally weighted disclosure indices that assigned identical scores to all disclosed environmental items. Although straightforward to apply, these approaches assume that all disclosure items are equally important and often fail to distinguish between qualitative narratives and substantive quantitative disclosures. More recent studies have adopted the Global Reporting Initiative (GRI 300 Environmental Standards), which provides a comprehensive framework covering key aspects of environmental performance, including energy use, greenhouse gas emissions, waste management, environmental investments, and environmental risk management. The GRI framework has become the most widely adopted benchmark because it improves the consistency, comparability, and comprehensiveness of sustainability reporting.

Building on this framework, the present study measures environmental sustainability disclosure using five environmental reporting dimensions derived from the GRI 300 Environmental Standards: energy consumption and efficiency, greenhouse gas emissions, environmental expenditure and investments, environmental training and awareness,

and environmental risk management. Unlike previous studies that assigned equal weights to disclosure items, this study constructs a composite Environmental Sustainability Disclosure Index using Principal Component Analysis (PCA). PCA generates objective statistical weights based on the contribution of each disclosure dimension to the overall variation in environmental reporting, thereby reducing researcher subjectivity, minimizing multicollinearity, and capturing the multidimensional nature of environmental disclosure. Consequently, the PCA-based index provides a more objective, reliable, and comprehensive measure of environmental sustainability disclosure than conventional equally weighted indices.

Accordingly, environmental sustainability disclosure serves as the dependent variable in this study because it reflects the extent to which listed manufacturing firms in Nigeria communicate their environmental performance and accountability. Its quality is expected to depend on firm characteristics and corporate governance mechanisms, which influence firms' resources, monitoring capacity, stakeholder responsiveness, and commitment to transparent environmental reporting.

Firm Characteristics and Environmental Sustainability Disclosure

Firm characteristics refer to the internal organizational attributes that distinguish one firm from another and influence its strategic decisions, operational capacity, and reporting behavior. These characteristics reflect a firm's demographic, financial, and structural features, which shape its ability to respond to stakeholder expectations and regulatory requirements (Zou & Stan, 1998; McKnight & Weir, 2008). Within the sustainability reporting literature, firm characteristics determine the resources, experience, and organizational capacity available for environmental management and disclosure (Zayol et al., 2021; Orajekwe & Ogbodo, 2023).

The nexus between firm characteristics and ESD is supported by several theoretical perspectives. Stakeholder Theory argues that firms with greater visibility face stronger pressure from investors, regulators, customers, and host communities to

disclose environmental information. Legitimacy Theory similarly suggests that firms use environmental disclosure to demonstrate conformity with societal expectations and maintain their social licence to operate. Resource Dependence Theory emphasizes that organizations with greater resources are better positioned to invest in environmental management systems and sustainability reporting, while Agency Theory contends that firm-specific characteristics influence managers' incentives to reduce information asymmetry through transparent disclosure.

Among the various firm characteristics examined in the literature, this study focuses on firm size and age because they consistently explain variations in environmental disclosure. Firm size reflects organizational visibility, financial capacity, and resource availability. Larger firms are generally expected to disclose more environmental information because they possess stronger reporting systems, greater financial resources, and are subject to higher public and regulatory scrutiny (Hasan & Hosain, 2015; Akhter et al, 2023; Ogundajo & Onakoya, 2016). Firm age represents organizational maturity, accumulated experience, and corporate reputation. Older firms are more likely to establish formal environmental reporting systems and disclose more comprehensive environmental information to preserve legitimacy and long-standing stakeholder relationships (Kabiru, 2020).

Accordingly, firm characteristics are conceptualized in this study as organizational attributes that influence firms' capacity and incentives to undertake environmental sustainability disclosure. Differences in firm size and age are therefore expected to explain variations in the quality and extent of environmental sustainability disclosure among listed manufacturing firms in Nigeria.

Theoretical Framework

Environmental sustainability disclosure (ESD) is a complex corporate reporting practice shaped by organizational characteristics, governance structures, stakeholder expectations, and institutional pressures. Consequently, no single theory adequately explains firms' environmental disclosure behavior. This study

adopts an integrated theoretical framework comprising stakeholder theory (Freeman, 1984), legitimacy theory (Dowling & Pfeffer, 1975; Suchman, 1995), agency theory (Jensen & Meckling, 1976), and resource dependence theory (Pfeffer & Salancik, 1978). Collectively, these theories explain why firms disclose environmental information and how firm characteristics and corporate governance influence the quality and extent of environmental sustainability disclosure.

Stakeholder theory argues that firms disclose environmental information to satisfy the expectations of investors, regulators, customers, employees, host communities, and other stakeholders whose support is essential for organizational survival. Manufacturing firms, because of their significant environmental impacts, experience greater stakeholder pressure to demonstrate accountability through transparent environmental reporting. Complementing this perspective, legitimacy theory posits that organizations operate under a social contract and therefore disclose environmental information to maintain societal approval and preserve their licence to operate. Firms with greater public visibility, particularly larger and more established organizations, are more likely to provide comprehensive environmental disclosures to demonstrate conformity with societal expectations and environmental regulations.

Agency theory explains environmental disclosure from a governance perspective by emphasizing that information asymmetry and conflicting interests between managers and shareholders create incentives for greater transparency. Effective governance mechanisms, particularly larger and more independent boards and greater gender diversity, strengthen managerial oversight, reduce agency conflicts, and encourage more credible and comprehensive environmental reporting. Resource dependence theory further extends this explanation by arguing that firms require critical external resources for long-term survival and competitiveness. Consequently, organizations with greater financial capacity, organizational maturity, and effective governance structures are better positioned to invest in environmental management systems and

sustainability reporting, while diverse and independent boards provide the expertise, external networks, and legitimacy necessary to respond to evolving stakeholder and regulatory expectations.

Although each theory offers a distinct explanation, they are complementary rather than competing. Stakeholder Theory explains the external pressure for environmental accountability; Legitimacy Theory explains the need to maintain social acceptance; Agency Theory emphasizes the governance mechanisms that enhance transparency and reduce information asymmetry; and Resource Dependence Theory explains how organizational resources and board capabilities enable firms to implement effective environmental reporting. Integrating these perspectives provides a more comprehensive explanation of environmental sustainability disclosure than relying on any single theory.

Accordingly, this study conceptualizes environmental sustainability disclosure as the outcome of interactions between firm characteristics and corporate governance mechanisms. Firm size and age represent organizational capacity, visibility, and accumulated legitimacy, while board size, board independence, and board gender diversity reflect governance quality and monitoring effectiveness. Together, these factors determine firms' ability, incentives, and accountability to provide comprehensive environmental sustainability disclosure among listed manufacturing firms in Nigeria.

2.8 Empirical Literature

Empirical evidence on ESD has expanded considerably over the past decade, reflecting growing interest in understanding the organizational factors that influence corporate environmental reporting. Although previous studies generally acknowledge that firm characteristics and corporate governance shape environmental disclosure, empirical findings remain inconsistent across countries and industries. These inconsistencies largely reflect differences in institutional quality, regulatory enforcement, environmental sensitivity of industries, disclosure measurement, and estimation techniques. The empirical literature is therefore synthesized under

three themes: firm characteristics, corporate governance, and the outcomes of environmental sustainability disclosure.

Firm Characteristics and Environmental Sustainability Disclosure

The empirical literature generally suggests that firm characteristics influence both the quality and extent of environmental sustainability disclosure. Across developed economies, evidence consistently indicates that larger and more established firms disclose more comprehensive environmental information because they possess greater financial resources, established reporting systems, stronger public visibility, and are exposed to greater stakeholder and regulatory pressures (Wang, 2017; Dilling, 2010; Amos et al., 2018; Agarwala et al., 2024; Al-Qudah & Houcine, 2024). These findings imply that organizational capacity and stakeholder exposure enhance firms' willingness and ability to disclose environmental information.

However, evidence relating to other firm characteristics remains far less conclusive. While several studies report that financially stronger and highly leveraged firms provide more extensive environmental disclosures because of greater investment capacity and creditor monitoring, others report insignificant or negative relationships. These divergent findings suggest that the influence of firm characteristics depends on contextual factors such as institutional quality, voluntary reporting regimes, ownership structures, and managerial priorities rather than firm attributes alone. Consequently, firm characteristics cannot be regarded as universally consistent determinants of environmental sustainability disclosure.

Evidence from Nigeria reflects similar inconsistencies. Although several studies report positive effects of firm size and age on environmental disclosure, others find weak or insignificant relationships. The lack of consensus indicates that the influence of firm characteristics varies across sectors and regulatory environments, highlighting the need for further sector-specific investigations within Nigeria's manufacturing industry.

Corporate Governance and Environmental Sustainability Disclosure

Corporate governance has increasingly emerged as a critical determinant of environmental sustainability disclosure because effective governance strengthens managerial oversight, accountability, and transparency. The majority of international studies report that governance mechanisms such as board independence, board size, board expertise, and gender diversity improve environmental reporting by enhancing board effectiveness and responsiveness to stakeholder expectations (Akhter et al, 2023; Aman & Bakar, 2018; Hanen et al., 2020; Casciello et al., 2025; Lewa et al., 2025). Similarly, gender-diverse boards are frequently associated with stronger sustainability reporting and improved corporate accountability.

Despite this broad consensus, empirical findings remain inconsistent regarding the effectiveness of specific governance mechanisms. Some studies report insignificant or even negative effects of board size and other governance variables, suggesting that governance structures alone do not necessarily improve environmental disclosure. Rather, their effectiveness depends on institutional enforcement, board independence in practice, organizational culture, and regulatory quality. This suggests that corporate governance influences environmental disclosure through the quality of board oversight rather than merely through board composition.

Within Nigeria, empirical evidence remains relatively limited and fragmented. Existing studies generally report positive effects of board independence and board size on environmental disclosure; however, they examine governance mechanisms in isolation and provide a limited understanding of how governance interacts with organizational characteristics to influence environmental reporting. Consequently, evidence explaining the combined influence of firm characteristics and corporate governance remains scarce.

Environmental Sustainability Disclosure and Corporate Outcomes

A growing body of literature examines the consequences of environmental sustainability

disclosure rather than its determinants. The dominant empirical evidence indicates that high-quality environmental disclosure enhances corporate reputation, investor confidence, firm value, financial performance, and access to capital by reducing information asymmetry and improving stakeholder confidence. However, some studies report weak or insignificant short-run financial effects, suggesting that the economic benefits of environmental disclosure are more likely to emerge over longer periods. Collectively, these findings reinforce the strategic importance of environmental sustainability disclosure while demonstrating that its benefits depend on firms' institutional and operating environments.

Research Gap

The empirical literature reveals broad agreement that firm characteristics and corporate governance influence environmental sustainability disclosure. Nevertheless, three important gaps remain. Existing evidence remains conceptually fragmented because most studies examine firm characteristics and corporate governance independently, providing only a partial explanation of environmental disclosure behavior despite their complementary roles in shaping corporate transparency. The Nigerian evidence is contextually limited, with most studies concentrating on oil and gas companies, financial institutions, or mixed-industry samples. Consequently, relatively little empirical evidence exists for the manufacturing sector, despite its substantial contribution to environmental pollution and its increasing exposure to sustainability reporting requirements.

Methodological limitations continue to constrain existing evidence. Most previous studies employ static panel estimation techniques and conventional equally weighted disclosure indices that emphasize disclosure quantity while inadequately capturing disclosure quality, multidimensionality, firm heterogeneity, and dynamic adjustment processes.

This study addresses these limitations by jointly examining the influence of firm characteristics and corporate governance on environmental sustainability disclosure among listed manufacturing firms in

Nigeria over the period 2014–2024. It constructs a composite Environmental Sustainability Disclosure Index based on the GRI 300 Environmental Standards using Principal Component Analysis (PCA) and applies the dynamic Panel Autoregressive Distributed Lag (Panel ARDL) model estimated through the Pooled Mean Group (PMG) estimator. By integrating organizational characteristics and governance mechanisms within a unified empirical framework, the study provides more robust theoretical, methodological, and empirical evidence on the determinants of environmental sustainability disclosure in Nigeria's manufacturing sector.

III. METHODOLOGY

This study adopts an *ex post facto* research design within a quantitative longitudinal panel framework to examine the influence of firm characteristics and corporate governance on environmental sustainability disclosure (ESD) among listed manufacturing firms in Nigeria over the period 2014–2025.

The population of the study comprises all manufacturing firms listed on the Nigerian Exchange Group (NGX) between 2014 and 2025. The manufacturing sector was selected because of its significant contribution to industrial emissions, energy consumption, waste generation, environmental pollution, and natural resource depletion. Furthermore, manufacturing firms are subject to greater environmental scrutiny from regulators, investors, host communities, and other stakeholders, making the sector an appropriate setting for examining the determinants of environmental sustainability disclosure.

A purposive sampling technique was employed to select firms that remained continuously listed on the NGX throughout the study period and consistently published complete financial, corporate governance, and environmental disclosure information. The study relies exclusively on secondary data extracted from the audited annual reports and sustainability reports of the sampled firms.

Measurement of Variables

The dependent variable in this study is ESD, while the independent variables comprise firm characteristics (firm size and firm age) and corporate governance variables (board size, board independence, and board gender diversity). ESD is measured using five environmental disclosure dimensions derived from the Global Reporting Initiative (GRI 300 Environmental Standards), namely: energy consumption and efficiency, greenhouse gas emissions, environmental expenditure and investment, environmental training and awareness, and environmental risk management.

To obtain a comprehensive measure of environmental sustainability disclosure, the five disclosure dimensions were combined into a composite Environmental Sustainability Disclosure (ESD) Index using principal component analysis (PCA). PCA generates objective statistical weights based on the contribution of each disclosure dimension to the overall variation in environmental reporting, thereby reducing subjectivity, minimizing multicollinearity, and producing a more reliable measure than conventional equally weighted disclosure indices. The first principal component is specified as

$$PC_1 = a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + a_5X_5 \dots \dots \dots Eq 1$$

where $a_1 - a_5$ are the eigenvector coefficients (component loadings) obtained from the PCA estimation.

- X₁ = Energy Consumption and Efficiency Disclosure
 - X₂ = Greenhouse Gas Emission Disclosure
 - X₃ = Environmental Expenditure and Investment Disclosure
 - X₄ = Environmental Training and Awareness Disclosure
 - X₅ = Environmental Risk Management Disclosure
- ESD Index is computed as:

$$ESD_i = \sum_{j=1}^5 a_j X_j \dots \dots \dots Eq 2$$

Model Specification

This study specifies environmental sustainability disclosure as a function of firm characteristics and corporate governance variables. The functional relationship is expressed as follows:

$$ESD = f(FSIZE, FAGE, BSIZE, BIND, BGD) \dots \dots \dots Eq 3$$

where ESD = environmental sustainability disclosure; FSIZE = firm size; FAGE = firm age; BSIZE= board size; BIND = board independence; BGD = board gender diversity

The econometric specification is presented as:

$$ESD_{it} = \beta_0 + \beta_1 FSIZE_{it} + \beta_2 FAGE_{it} + \beta_3 BSIZE_{it} + \beta_4 BIND_{it} + \beta_5 BGD_{it} + \epsilon_{it} \dots \dots \dots Eq 4$$

where i= cross-sectional units (firms), t= time (2014–2025), β_0 = intercept, $\beta_1 - \beta_4$ are the parameters to be estimated, and ϵ_{it} = error term.

Estimation Technique

The study employs the Panel Autoregressive Distributed Lag (Panel ARDL) model estimated using the Pooled Mean Group (PMG) estimator developed by Pesaran, Shin, and Smith (1999). The estimator is appropriate because it simultaneously estimates the short-run and long-run relationships among variables, accommodates variables integrated of order I(0) and I(1), and incorporates an error correction mechanism to capture the speed of adjustment toward long-run equilibrium. The PMG estimator permits heterogeneous short-run dynamics across firms while imposing homogeneous long-run coefficients, making it suitable for Nigerian manufacturing firms operating under a common regulatory framework but exhibiting firm-specific short-run responses. The general Panel ARDL-PMG model is specified as: The general Panel ARDL (PMG) model is expressed as:

$$\Delta ESD_{it} = \phi_i (ESD_{it-1} - \theta_i X_{it}) + \sum_{j=1}^{p-1} \lambda_{ij} \Delta ESD_{it-j} + \sum_{j=1}^{q-1} \delta_{ij} \Delta X_{it-j} + \mu_i + \epsilon_{it} \dots \dots \dots Eq 5$$

where ϕ_i = the error correction coefficient, θ_i = the long-run coefficients, λ_{ij} and δ_{ij} = the short-run

dynamics, μ_i = firm-specific effects, and ϵ_{it} = the error term.

The panel unit root test was conducted using the Levin, Lin, and Chu (LLC) and Im, Pesaran, and Shin (IPS) tests to determine the stationarity and order of integration of the variables before estimating the Panel ARDL model. Employing both tests improves the robustness of the stationarity assessment and verifies that the variables are integrated of order I(0) or I(1), a prerequisite for the Panel ARDL-PMG estimation. Establishing stationarity prevents spurious regression results and ensures the validity and reliability of the estimated short-run and long-run relationships.

IV. RESULTS AND DISCUSSION

Principal Component Analysis (PCA)

PCA was performed to construct the ESD index. The eigenvalues in Table 1 reveal robust data representation. The first PCA with eigenvalues greater than one accounted for 81.60% of the total variance, exceeding the 80% threshold. The Kaiser–Meyer–Olkin (KMO) statistic was used to determine the suitability of the five ESDs to be combined into a single ESD index using PCA.

Table 1: Total Variance Explained (Principal Component Analysis)

Component	Eigenvalue	Variance Explained (%)	Cumulative (%)	KMO and Bartlett's Test	
				Test	Statistic
PC1	4.08	81.60	81.60	Kaiser-Meyer-Olkin (KMO)	0.841
PC2	0.42	8.40	90.00	Bartlett's Test of Sphericity (χ^2)	312.487
PC3	0.26	5.20	95.20	Degrees of Freedom	10
PC4	0.16	3.20	98.40	Probability	0.000
PC5	0.08	1.60	100.00		

The Kaiser-Meyer-Olkin statistic of 0.841 indicates that the sample is highly adequate for PCA, while Bartlett's Test of Sphericity is statistically significant ($\chi^2 = 312.487$, $p < 0.001$), confirming that ESD indicators are sufficiently correlated to justify PCA. The results further reveal that the first principal component has an eigenvalue of 4.08, explaining

81.60% of the total variance in the five ESD indicators. Since the first component exceeds both the Kaiser criterion (eigenvalue > 1) and the 80% cumulative variance threshold, it was retained to construct the ESD Index.

Table 2 Descriptive Statistics

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.
ESD	0.681	0.695	0.982	0.214	0.158	-0.437	2.684	2.514	0.285
FSIZE	17.842	17.765	20.914	14.602	1.326	0.152	2.418	1.728	0.421
FAGE	34.185	32.000	71.000	8.000	15.247	0.538	2.731	3.264	0.195
BFSIZE	9.284	9.000	16.000	5.000	2.148	0.471	2.894	2.105	0.349
BIND	0.634	0.625	0.889	0.333	0.126	-0.284	2.507	1.884	0.390
BGD	0.274	0.250	0.556	0.000	0.134	0.603	2.961	3.412	0.182

The descriptive statistics in Table 2 indicate that the mean ESD Index of 0.681 reveals that the listed manufacturing firms disclosed, on average, 68.1% of the environmental information captured by the PCA-based index. The standard deviation (0.158) indicates moderate variation in disclosure practices across

firms. Firm size has a mean of 17.842, reflecting moderate differences in total assets, while the average firm age is 34.19 years, ranging from 8 years (BUA Foods Plc) to 71 years (Guinness Nigeria Plc), indicating substantial industry experience.

The average board size was 9.28 directors, with board independence averaging 63.4% and board gender diversity 27.4%, suggesting reasonable board independence but relatively low female representation. The skewness and kurtosis values indicate approximate normality, while the

insignificant Jarque–Bera statistics ($p > 0.05$) confirm that the variables are normally distributed, supporting the suitability of the data for subsequent Panel ARDL-PMG estimation.

Table 3: Levin, Lin and Chu (LLC) Panel Unit Root Test

Variable	I(0)	Prob.	I(1)	Prob.	I(0)	Prob.	I(1)	Prob.	Order of Integration
Levin, Lin and Chu (LLC)					Im, Pesaran and Shin (IPS)				
ESD	-2.864	0.002	-	-	-2.571	0.005	-	-	I(0)
FSIZE	-1.236	0.108	-5.942	0.000	-1.405	0.080	-6.118	0.000	I(1)
FAGE	-3.487	0.000	-	-	-3.108	0.001	-	-	I(0)
BSIZE	-2.971	0.001	-	-	-2.846	0.002	-	-	I(0)
BIND	-1.182	0.119	-6.213	0.000	-1.298	0.097	-5.764	0.000	I(1)
BGD	-1.094	0.137	-4.885	0.000	-1.166	0.122	-5.027	0.000	I(1)

The results in Table 3, presenting the Levin, Lin, and Chu (LLC) and Im, Pesaran, and Shin (IPS) panel unit root test results, reveal a mixed order of integration among the variables. Specifically, ESD, FAGE, and BSIZE are stationary at levels I(0). In contrast, FSIZE, BIND, and BGD are stationary at I(1) first differencing. This combination of I(0) and I(1) variables satisfies the key requirement for estimating the Panel Autoregressive Distributed Lag (Panel ARDL) model using the Pooled Mean Group (PMG) estimator. Consequently, the Panel ARDL-PMG approach is appropriate for examining both the short-run and long-run relationships between firm characteristics, corporate governance, and environmental sustainability disclosure among listed manufacturing firms in Nigeria.

The results in Table 4 show a chi-square statistic of 5.184, which implies that the long-run coefficients are homogeneous across the sampled manufacturing firms, while short-run dynamics are allowed to differ across firms.

Bound Test Results

The bounds test was conducted to determine whether a long-run equilibrium relationship exists between the dependent variable (ESD) and the explanatory variables.

Table 5: Panel ARDL Bounds Test Results

Test Statistic	Value	Critical Value Bounds (5%)		
		I(0)	I(1)	Decision
F-Statistic	6.842	2.62	3.79	Cointegration
K	5			

The results in Table 5 show that the calculated F-statistic (6.842) exceeds the upper critical bound at the 5% significance level (3.79). The results reveal a long-run equilibrium nexus between ESD and the explanatory variable. Thus, justifying the estimation of the Panel ARDL-PMG ECM to estimate both the short-run and long-run effects of firm characteristics and corporate governance on ESD among listed manufacturing firms in Nigeria.

Hausman specification test

The Hausman specification test was conducted to determine the most appropriate estimator for the panel ARDL model.

Table 4: Hausman Specification Test (PMG versus MG)

Test	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.	Decision
PMG vs MG	5.184	5	0.393	PMG Preferred

Table 6: Panel ARDL-PMG Long-run Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.	Test	Test Statistic (Prob.)	Decision
Panel A: Long-Run Results					Panel B: Diagnostic Test		
F _{SIZE}	0.486	0.092	5.283	0.000	Breusch-Godfrey (LM) Serial Correlation Test	1.437 (0.239)	No Serial Correlation
F _{AGE}	0.173	0.057	3.035	0.003	Breusch-Pagan-Godfrey Heteroskedasticity Test	8.162 (0.147)	Homoskedastic Residuals
B _{SIZE}	0.362	0.081	4.469	0.000	Jarque-Bera Normality Test	1.926 (0.382)	Normally Distributed
B _{IND}	0.914	0.186	4.914	0.000	Ramsey RESET Test	0.846 (0.399)	Model Correctly Specified
B _{GD}	0.681	0.159	4.283	0.000	Pesaran Cross-sectional Dependence (CD) Test	0.917 (0.359)	No Cross-sectional Dependence
C	-7.438	1.561	-4.765	0.000	Variance Inflation Factor (Mean VIF)	2.41	No Multicollinearity
Short-Run PMG Results					The diagnostic results indicate that the estimated Panel ARDL-PMG model satisfies the key econometric assumptions. Thus, the results are unbiased, efficient, and consistent, thereby enhancing the validity, robustness, and reliability of the empirical findings and the inferences drawn on ESD among the listed manufacturing firms in Nigeria.		
ECM(-1)	-0.817	0.064	-12.766	0.000			
ΔF _{SIZE}	0.218	0.071	3.070	0.002			
ΔF _{AGE}	0.064	0.028	2.286	0.023			
ΔB _{SIZE}	0.157	0.054	2.907	0.004			
ΔB _{IND}	0.381	0.094	4.053	0.000			
ΔB _{GD}	0.246	0.082	3.000	0.003			

From the results in Table 6, F_{SIZE} positively and significantly influences ESD by 48.6%, which implies that larger manufacturing firms disclose significantly more environmental sustainability information than smaller firms in the long run. Larger firms possess greater financial resources, more sophisticated reporting systems, and are exposed to stronger scrutiny from regulators, investors, host communities, and environmental advocacy groups. The results support stakeholder theory, legitimacy theory, and resource dependence theory and are consistent with Wang (2017), Dilling (2010), Agarwala et al. (2024), Onyinye and Amakor (2019), Kabiru (2020), Amos et al. (2018), and Al-Qudah and Houcine (2024). However, it contradicts Sulaiman et al. (2018) and Moruff et al. (2021), who reported insignificant relationships.

The positive and significant impact of F_{AGE} on ESD by 17.3% reveals that older manufacturing firms disclose more environmental sustainability information than younger firms. Older firms have

accumulated reporting experience, established governance structures, and stronger stakeholder relationships, enabling them to adopt more comprehensive sustainability reporting practices. The

results are consistent with those of legitimacy theory and stakeholder theory, which argue that mature firms strive to maintain organizational legitimacy and stakeholder confidence through transparent reporting. The results are consistent with those of Kabiru (2020), Innocent and Gloria (2018), Hasan and Hosain (2015), and Ong and Djajadikerta (2017), but differ from those of Moruff et al. (2021) and Ruhana and Hidayah (2019), who found no significant relationship.

B_{SIZE} impact on ESD by 36.2%, indicating that firms with larger boards provide more comprehensive ESD. Larger boards contribute broader expertise, stronger monitoring capacity, and greater representation of stakeholder interests, thereby improving environmental reporting quality. The

results are consistent with agency theory, stakeholder theory, and resource dependence theory, and the findings of Casciello et al. (2025), Lewa et al. (2025), Adebayo et al. (2023), and Moruff et al. (2021). However, this contrasts with Zhu et al. (2024) and Giannarakis (2014), who argued that excessively large boards may reduce decision-making efficiency.

BIND has a long-run positive and significant impact on ESD by 91.4%, implying that increasing the proportion of independent directors substantially enhances ESD. Independent directors strengthen board oversight, improve transparency, and reduce agency conflicts by ensuring greater managerial accountability. The results support agency theory, stakeholder theory, legitimacy theory, and resource dependence theory, all of which emphasize the governance role of independent directors in promoting corporate transparency. The results corroborate those of Aman and Bakar (2018), Hanen et al. (2020), Adebayo et al. (2023), and Moruff et al. (2021), although they differ from those of Zhu et al. (2024) and Ilewa et al. (2024), who reported insignificant effects.

BGD is positive and significant at 68.1%, indicating that firms with greater female representation on their boards disclose significantly more ESD. Female directors contribute diverse perspectives, stronger ethical orientation, and greater sensitivity to stakeholder concerns, thereby promoting environmental transparency. Results stakeholder theory, agency theory, legitimacy theory, and resource dependence theory. The results are consistent with those of Van et al. (2025), Casciello et al. (2025), Lewa et al. (2025), and Gwar et al. (2025), who reported that board gender diversity enhances sustainability reporting quality.

Short-run PMG Results

The short-run Panel ARDL-PMG estimates reveal that ECM(-1) is negative and significant at 81.7%, confirming the existence of a stable long-run equilibrium nexus between ESD and the explanatory variables. The results reveal that approximately 81.7% of any short-run disequilibrium is corrected within one year, indicating a relatively rapid adjustment towards long-run equilibrium.

Overall, the results show that firm characteristics and corporate governance mechanisms significantly influence ESD among listed manufacturing firms in Nigeria. While firm size and age strengthen firms' capacity to disclose environmental information, governance variables, particularly board independence and gender diversity, play a more prominent role in enhancing corporate environmental transparency and accountability.

V. CONCLUSION, RESEARCH GAP, CONTRIBUTIONS AND RECOMMENDATIONS

This study examined the influence of firm characteristics and corporate governance on ESD among listed manufacturing firms in Nigeria from 2014 to 2025 using the panel ARDL-PMG estimator. The results reveal that firm size, firm age, board size, board independence, and board gender diversity positively and significantly influence ESD in both the long run and short run. The ECM negative error correction term confirms a stable long-run equilibrium relationship.

This study fills important gaps by jointly examining firm characteristics and corporate governance, constructing a PCA-based ESD Index to eliminate subjective weighting, and applying the dynamic panel ARDL-PMG model instead of conventional static panel techniques. These methodological improvements provide more robust evidence on the determinants of environmental sustainability disclosure in Nigeria. Methodologically, it demonstrates the usefulness of PCA and Panel ARDL-PMG in sustainability research, while empirically providing recent evidence for the Nigerian manufacturing sector.

Based on the findings, manufacturing firms should strengthen board independence and increase female representation on corporate boards to improve environmental transparency. Firms should also invest in effective environmental management and reporting systems. Furthermore, regulators should strengthen the enforcement of sustainability reporting requirements and encourage compliance with the Global Reporting Initiative (GRI) Standards. Overall,

improving corporate governance and organizational capacity will enhance environmental sustainability disclosure, strengthen stakeholder confidence, and promote sustainable industrial development in Nigeria.

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