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BOARD CHARACTERISTICS AND CARBON EMISSION DISCLOSURE: EVIDENCE FROM LISTED MANUFACTURING FIRMS IN NIGERIA

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ABSTRACT

The increasing global concern over climate change has heightened demands for business transparency regarding greenhouse gas emissions. The disclosure of carbon emissions has become increasingly important, but research on the governance elements that influences such disclosure is still scarce in emerging economies, especially in Nigeria. This study explores the effect of board characteristics on the level of carbon emission disclosure among listed manufacturing firms in Nigeria. Specifically, this study investigates the effect of board independence, board gender diversity, board nationality, board commitment, and sustainability/environmental committee as determinants of carbon emission disclosure. The study is anchored on Agency Theory, Stakeholder Theory, and Resource Dependence Theory to underpin the study. The study adopts an ex-post facto research design and utilizes a balanced panel dataset of 45 listed manufacturing firms and 450 firm-year observations covering the period 2015 - 2024 using Panel-Corrected Standard Errors (PCSE) regression. The findings revealed that board gender diversity ($\beta = 0.245$, $p < 0.001$), board nationality ($\beta = 0.136$, $p < 0.001$), and sustainability/environmental committees ($\beta = 0.138$, $p < 0.001$) have significant positive effects on carbon emission disclosure. Board independence ($\beta = 0.096$, p 0.170) and board commitment ($\beta = 0.176$, $p = 0.084$) have positive but statistically insignificant effects. The findings provide empirical support for Stakeholder Theory and Resource Dependence Theory in explaining carbon emission disclosure practices among Nigerian listed manufacturing firms. Based on the findings, the study recommends straightening gender and nationality diversity on corporate boards and enhancing the effectiveness of sustainability/environmental committees to improve carbon emission disclosure among listed manufacturing firms in Nigeria.

JEL Classifications: G34, M14, M41

1. INTRODUCTION

The manufacturing sector continues to be a key driver of economic growth, industrialization and job creation, and makes large contributions to GDP in both developed and developing economies. Manufacturing firms play a crucial role in the country's productivity, technological growth, and economic sustainability. According to the World Bank (2024), the sector contributes a significant share of value-added output. Manufacturing industries are likewise identified as an important source of employment and economic diversity, particularly in emerging economies (United Nations Industrial Development Organization, 2023). The manufacturing sector has a major strategic role in encouraging economic development. In this sense, the manufacturing sector accounted for about 14.79% of Nigeria nominal GDP in the first quarter of 2024, according to the National Bureau of Statistics (2024). This is essentially in line with the World Bank's estimate of 13.5% of Nigeria's GDP in the same year. Beyond mere numbers, the industry sustains livelihoods through food processing, cement production, agro-allied, consumer goods manufacturing, chemical and industrial processing (Intelpoint, 2024).

While manufacturing operations are well-known to contribute significantly to the economy, they are also major contributors to environmental degradation and greenhouse gas (GHG) emissions. An expansion in production activities can contribute to firms experiencing greater environmental impacts through greater consumption of energy and natural resources, and consequently, higher greenhouse gas emissions. This truth has propelled climate change to the centre of policy debates, investor engagements and regulatory agendas in the 21st century. The main reasons for global warming and climate disturbance are the human activities that involve the release of carbon emissions such as carbon dioxide (CO_2), nitrogen oxide (N_2O), methane (CH_4), and chlorofluorocarbons and other greenhouse gases (GHGs) (United Nations Framework Convention on Climate Change, 2012).

Nigeria's long-running electrical supply problems further exacerbate the problem. With unreliable national grid, factories have had to provide their own electricity, mostly from diesel and gas-fired turbines, both of which are high-emission energy sources. In 2024, Nigeria recorded approximately 131.91 million tonnes CO_2 emissions, excluding emissions from land use, land-use change and forestry (LULUCF) (International Energy Agency, 2025; Emission Database for Global Atmospheric Research, 2025). The World Economic Forum (2020) has cautioned that failure to mitigate climate change poses significant economic and physical hazards. Globally, firms, particularly in developed economies, have responded by boosting environmental disclosures and adopting actions to mitigate the impact of their operations (KPMG, 2022). These pressures have bolstered by decarbonisation targets in the Paris Agreement (IPCC, 2018). As a developing country, Nigeria has been trying to address its major environmental problems. The World Bank 2022 Global Gas Flaring Tracker ranks the country ninth in the world for gas flaring, whereas the World Resources Institute classified the country as the 90th highest provider of carbon emissions as of 2019.

Currently, carbon emissions disclosure in Nigeria is still primarily voluntary. However, the regulatory landscape is shifting. The Financial Reporting Council of Nigeria (FRCN) has released a roadmap for adopting IFRS S1 and IFRS S2 sustainability disclosure standards. In phase 3 of this strategy, all public entities (except government bodies) will be required to produce sustainability reports for accounting periods commencing on or after January 1, 2028.

Small and medium-sized enterprises will follow with the mandated adoption commencing from January 1, 2030.

Against this backdrop, corporate governance mechanisms, particularly board characteristics, have emerged as a major determinant of both the scope and quality of carbon emission disclosure. Boards of directors have a responsibility to provide oversight of management, to ensure accountability and to match business actions with the expectations of a broader variety of stakeholders. The composition of the board in terms of independence, gender diversity, nationality, commitment, and existence of a sustainability/environmental committee is increasingly viewed as a determinant of how seriously a firm approaches climate-related disclosure. The effectiveness of the board in providing strategic oversight may therefore influence the extent to which firms recognise, manage and communicate their environmental responsibilities.

Notwithstanding, the growing attention to environmental reporting, the disclosure of carbon emission (CED) remains comparatively neglected by Nigerian manufacturing firms relative to their counterparts in developed markets. There are relatively few empirical studies on this subject, making it a relevant and under-explored area of inquiry. More importantly, the strategic oversight function of boards in driving environmental reporting practices has not yet been thoroughly examined in this context. The strengthening of corporate governance is generally considered a potential route to decarbonisation, and sustainable development, making the examination of board characteristics and carbon emission disclosure particularly relevant.

Several prior studies have explored related areas, such as the links between financial performance and carbon emission disclosure (Appah et al., 2025; Emmanuel et al., 2023; Akhanolu et al., 2023; Khatib et al., 2023; Onyebuenyi et al., 2023; Mihail et al., 2022; Downar et al., 2021; Abubakar et al., 2021; Alsaifi et al., 2019;), between firm value and carbon emission disclosure (Issa et al., 2024; Kurnia et al., 2020; Muhammad et al., 2020; Mohammed & Aisa, 2020), and between earnings management and carbon emission disclosure (Asyifa & Burhany, 2020; Astari et al., 2020). Some studies have also examined board characteristics and carbon emission disclosure directly (Adeleke et al., 2025; Mansour et al., 2025; Mardini and Lahyani (2024); Ladini et al., 2024; Bedi and Singh, 2024; Saadah et al., 2024; Chakraborty and Dey, 2023; Saheed et al., 2021). Although the majority of these investigations were carried out in European and Asian contexts, empirical evidence from African countries, including Nigeria, remains relatively scarce.

The study is driven by the increasing discussion on carbon emissions and climate change. Prior literature has examined board characteristics and sustainability disclosures in general (Mamun, 2023; Abdulkadir et al., 2022; Yahaya et al., 2022; Christopher et al., 2022; Modozie & Amahalu, 2022; Banno et al., 2021; Ndalu et al., 2021; Agyemang et al., 2020), but few targeted studies exist on carbon emission disclosure among Nigerian Manufacturing firms. Although previous studies have examined corporate governance and environmental disclosure, much of the existing evidence focuses on broader environmental, sustainability or corporate social responsibility disclosure rather than specifically examining carbon emission disclosure. This limits the extent to which existing findings can explain the governance determinants of firms' carbon-related transparency. In addition, the theoretical explanation of the relationship between board characteristics and carbon emission disclosure remains fragmented. This study therefore seeks to fill this gap and generate new empirical insights for scholars, policymakers, regulators, practitioners, and corporate stakeholders. Accordingly, the

study addresses five research questions concerning whether and to what extent board independence, board gender diversity, board nationality, board commitment, and sustainability/environmental committee influence carbon emission disclosure among listed manufacturing firms in Nigeria. The main purpose of this study is to examine the effect of board characteristics on carbon emission disclosure of listed manufacturing firms in Nigeria. Specifically, it examines the effect of board independence, board gender diversity, board nationality, board commitment, and sustainability/environmental committee on carbon emission disclosure. The hypotheses of the study were that there is no significant effect of board characteristics on carbon emission disclosure of listed manufacturing firms in Nigeria.

2. LITERATURE REVIEW

This section reviews the conceptual foundations, relevant empirical studies, and theoretical framework underpinning the study.

2.1 CONCEPTUAL REVIEW

According to Hermawan et al. (2018), emissions are any type of substance that is released into the air. For example, greenhouse gases from factories and power plants. The common types of emissions are carbon monoxide (CO), hydrogen (HC), methane (CH4), dinitrogen (N_20), hydroflucarbon (HFC), perflurocarbon (PFC), and Sulphur hexafluoride (SF6) that are hazardous to the quality of the air (Budiharta & Kacaribu, 2020).

Carbon emission disclosure is the information which a corporation makes publicly available regarding its carbon-related performance and climate strategies to its various stakeholders (Pitrakkos & Maroun, 2019). Velte et al. (2020) defined CED as the carbon-specific component of a company's broader environmental reporting which includes emission statistics,, climate-related strategies, associated risks, and potential opportunities arising from climate change impacts.

The board of directors is the soul of any company. Directors might be independent or non-independent. Non-independent directors generally have direct operational responsibilities in the firm. An independent director on the other hand refers to a member of the board of directors who has no meaningful financial or personal relationship with the corporation or its connected parties except from the sitting allowances paid during board meetings (Amahalu & Osonwa, 2023). Empirical evidence is substantially in favour of the assumption that a higher proportion of independent directors on the board is associated with more robust carbon emission disclosure (Abdulkadir et al., 2025; Saraswati et al., 2020).

Amorelli and Garcia-Sanchez (2020) define board gender diversity as the representation of female directors on the board, emphasising their contribution to ethical decision-making and stakeholder inclusiveness. (Endo, 2025) looks at it from an equity viewpoint, in terms of how companies integrate gender considerations in strategic decision-making. Board nationality refers to the diversity of national backgrounds among a company's directors (Masulis et al., 2022). Foreign directors are supposed to help companies better comprehend and respond to international stakeholder expectations on sustainability and environmental practice.

Board commitment refers to the degree to which board members are actively and genuinely engaged in the affairs of the company they oversee (Al-Matari, 2024). Regular attendance at board meetings suggest directors are actively involved in assessing problems, exercising judgement and representing the interests of shareholders.

A sustainability or environmental committee is a dedicated body within which the company is responsible for the management environmental matters (Okudo and Amahalu, 2021). According to Khatri (2025), this refers to a board subcommittee established to monitor the company's environmental impact, including sustainability performance, environmental risk management, and corporate social responsibility (CSR). Liao et al. (2015) propose that the existence of an environmental committee supports better transparency around emissions, as it provides organised oversight of environmental hazards and helps alleviate the larger risks connected with climate change.

2.2 EMPIRICAL REVIEW

This section discusses the empirical evidence regarding board characteristics and carbon emission disclosure.

Saraswati et al. (2021) investigated 36 Indonesian manufacturing companies from 2015 - 2018 and found that there is a positive and significant relationship between independent directors and disclosure of carbon emission based on multiple regression analysis and drawing on legitimacy and stakeholders theories. Lahyani (2022) analysed 120 non-financial French listed companies from 2010 to 2019 using GMM estimation, similarly revealed a significant favourable influence of board independence on carbon disclosure. Amahalu et al. (2025), Ezekiel et al. (2024), and Joel et al. (2023) from Nigeria perspectives all indicate a substantial positive association between board independence and carbon emission disclosure. On the contrary, Mahentra et al. (2024), Suzana et al. (2023), Musa and Alqubaysi (2023), Sari and Hudaya (2023), Randanu et al. (2022) find no significant relationship between independent directors and carbon emission disclosure.

Recent empirical studies increasingly recognised board gender diversity as a key governance strategy in determining firms' carbon disclosure decisions. (Barroso et al., 2024; Anand et al., 2023). Gonenc and Krasnikova (2022) drew on a large international dataset of 22,841 firm-year observations from 38 countries between the years 2010 and 2019, grounded in agency and resource dependence theories. The study found a strong positive association between the proportion of female directors and voluntary carbon emission disclosure. Findings from Nigeria also tend toward positive and statistically significant associations (Nwoye et al., 2022; Adelegan & Fagbeja, 2021), though some mixed evidence exists.

The rationale for research on board nationality and carbon disclosure is the claim that foreign directors bring worldwide reporting requirements and climate awareness into corporate governance. In South Korea, Kim and Lee (2023) examined the relationship between board diversity and corporate carbon disclosure among South Korean firms. Their results showed that firms with foreign directors disclosed more information about carbon emission than those with domestic board members. However, empirical evidence from Nigeria on board nationality and carbon emission disclosure remains limited but is gradually emerging. Akpan (2025) found that board nationality diversity significantly influenced carbon-related disclosure among industrial goods companies listed on the Nigerian Exchange Group (NGX). Salvation et al. (2021) found that Nigerian manufacturing firms with more nationality-diverse boards disclosed more environmental information. On the contrary, Astuti and Setiany (2021) could not find any significant effect of board nationality on carbon emissions disclosure in their study of Indonesian manufacturing firms from 2017 to 2019.

The evidence on board meeting attendance and environmental disclosure is mostly positive. According to Bappah et al. (2025), Almaqtari et al. (2023), Abdulkadir (2023), Uwaigbe et al. (2022), Sekarlangit and Wardhani (2021), higher board involvement considerably improves environmental disclosures. In the European context, sustainability environmental committees are always related to better environmental and carbon reporting. Khatri and Giskas (2025) observed that organisations with dedicated sustainability committees produced much better disclosure quality especially when external assurance was included, helping to defend against greenwashing. Karaman et al. (2025) similarly discovered that environmental committees enhanced the relationship between board composition and sustainable supply chain practices.

Given Nigeria's perspective, the literature on sustainability or environmental committees are more limited. Yahaya et al. (2022) found that sustainability committees had a positive influence on the level of environmental information disclosed by consumer goods companies. However, the study by Adeleke et al. (2025) on 22 Nigerian listed firms from 2018 to 2022 revealed that the establishment of a board sustainability committee had no meaningful effect on climate change measures.

The empirical evidence on the relationship between board characteristics and carbon emission disclosure remains mixed. While some studies report positive relationships, others document insignificant or, in some cases, negative relationships. These divergent findings may partly reflect differences in research design and methodological choices across studies. In particular, prior studies differ in their sample sizes and sectoral composition, periods covered, and estimation techniques employed. Methodological and contextual differences suggest that findings from previous studies may not be directly generalised to listed manufacturing firms in Nigeria. The present study therefore provides additional evidence by focusing specifically on listed manufacturing firms over the 2015 - 2024 period and examining multiple board characteristics simultaneously in relation to carbon emission disclosure. The use of a panel-corrected standard errors (PCSE) approach further provides a basis for obtaining robust inference in the presence of potential panel-specific disturbances.

No single theory is sufficient to explain differences in carbon emission disclosure across firms. In addition to others, theories like agency theory, stakeholder theory , and resource dependence theory are claimed to be useful in a combined framework to explain carbon emission disclosure (Sundarasen et al., 2024). Thus, this study will mainly depend on these three foundational theories to explain the relationship between board characteristics and carbon emission disclosure.

Agency theory depends on the premise that the separation of ownership from management leads to divergent interests, information asymmetry, and a need for monitoring. From this perspective, board characteristics are a determinant of the effectiveness of the management of agency conflicts. A higher proportion of independent directors is expected to boost the quality of oversight and curb the managerial scope to withhold or distort carbon-related information. Likewise, directors who attend meetings regularly are in a stronger position to examine environmental policies and hold management accountable for disclosure practices.

Stakeholder theory (Freeman, 1984), extends the scope of corporate accountability beyond shareholders to a broader range of stakeholders such as regulators, consumers, employees, and communities. In this context, independent directors are monitors of management opportunism and advocates of environmental disclosure. Female directors, through their

greater attentiveness to climate change as stakeholder concern, are also expected to support environmental reporting.

Resource Dependence Theory (RDT) was created by Pfeffer and Salancik (1978) and conceptualises companies as open systems that are reliant on their external environment for key resources. In this view, the board of directors is not just a monitoring body but also a bridge to external resources such as human capital, expertise, legitimacy, and networks that assist companies to deal with environmental constraints. In line with this approach, Edacherian et al. (2024) contend that the board of directors is a fundamental mechanism for resource provision, which allows offering companies to gain substantial benefits. Empirical evidence suggests that female directors contribute positively to improving carbon-related information disclosure, bringing stronger ethical orientation and stakeholder sensitivity (Khan et al., 2022). Foreign directors provide access to international capital markets and investors that are increasingly seeking climate transparency. Also, sustainability or environmental committees provide a structural institutionalisation of RDT, embedding environmental expertise at the board level and enabling firms to deal more effectively with regulators, stakeholders, and environmental challenges.

The research framework is shown below:

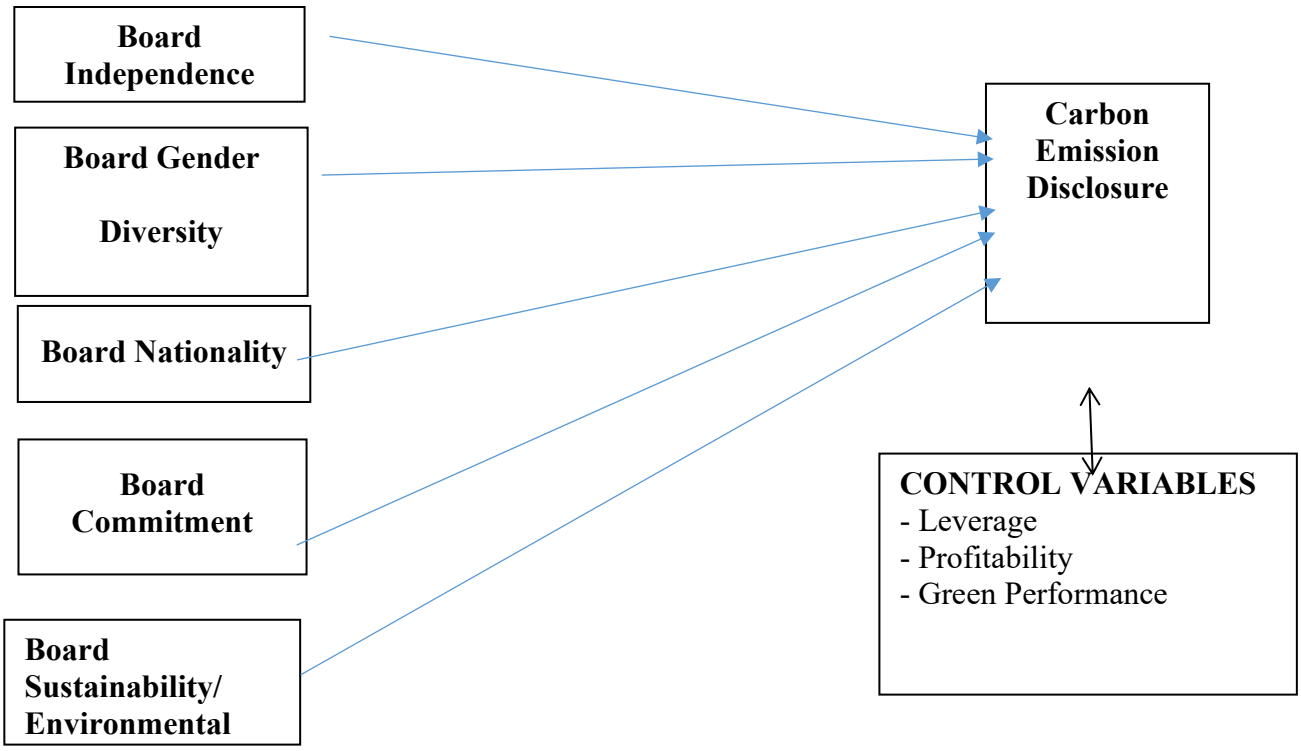

Figure 1
Conceptual framework

The above framework proposes that board characteristics, comprising board independence, board gender diversity, board nationality, board commitment, and sustainability/environmental committee, influence the level of carbon emission of listed manufacturing firms in Nigeria. The arrows from the respective board characteristics to carbon emission disclosure represent the hypothesized relationships examined in the study. The framework also incorporates leverage, profitability and green performance as control variables. These variables are included to account for other firm-specific factors that may influence carbon emission disclosure and thereby provide a more robust assessment of the relationship between board characteristics and carbon emission disclosure.

3. METHOD AND DATA

This study adopts a quantitative research design. Specifically, an ex-post facto (after the fact) design was used. This design is appropriate as the study examines the impact of the existing board characteristics on historical carbon emission disclosure data obtained from annual and sustainability reports.

The population of the study comprised 50 listed firms on the Nigerian Exchange Group (NGX) within the scope of the study. The study covered the period from 2015 to 2024, representing a ten-year period. This period was purposefully selected as it begins after the global financial crisis had largely stabilised, coincides with the adoption of the Paris Agreement in 2015, and encompasses a period of major economic reform in Nigeria.

From the identified population, firms were assessed based on the availability of the information required for the measurement of the dependent, explanatory and control variables. Five firms were excluded because the required data were not available for some years during the study period. The remaining 45 firms with the required data for the entire study period

constituted the final sample. Consequently, the study generated a balanced panel of 450 firm-year observations (45 firms x 10 years).

Table 1 shows the distribution of the sample firms in the study.

Table 1
Sample Selection Procedure

(A) Sample selection		
Total number of listed Manufacturing firms	constituting the study population	50
Less: Firms excluded due to failure to satisfy the data availability/ completeness Criterion		(5)
Final Sample size		45
Number of years covered		10
Total firm-year observations		450

The five firms excluded from the study due to the unavailability of required data during the study period were Ellah Lakes Plc, SCOA Nigeria Plc, Mecure Industries Plc, Premier Paints Plc, and Aluminium Extrusion Industries Plc.

(B) Industry Composition		
Industry	Number of firms	%
Agriculture	4	9
Conglomerate	5	11
Consumer goods	15	33
Healthcare	3	7
Industrial goods	8	18
Natural Resources	3	7
Oil and gas	7	15
Total	45	100

Source: Author's Compilation (2026).

3.1 Measurement of Carbon Emission Disclosure

Carbon emission disclosure (CED) was measured using Seven disclosure indicators contained in GRI 305: Emissions 2016, namely: GRI 305 - 1 (Direct/Scope 1 GHG emissions), GRI 305 - 2 (Energy Indirect/Scope 2 GHG emissions), GRI 305 - 3 (Other Indirect/Scope 3 GHG emissions), GRI 305 - 4 (GHG emissions intensity), GRI 305 - 5 (Reduction of GHG emissions), GRI 305 - 6 (Emission of ozone-depleting substances), and GRI 305 - 7 (NOx, SOx and other significant air emissions). Each disclosure indicator was assessed using a dichotomous content-↓↓analysis procedure. A score of one (1) was assigned where the firms disclosed the relevant GRI information, while zero (0) was assigned where the relevant information was not disclosed. The individual scores were then aggregated and divided by the total number of applicable indicators (Seven) to obtain the Carbon Emission Disclosure Index (CEDI).

The index was calculated as follows:

$$CEDI = \frac{\sum Dij}{MXCQ}$$

Where:

CEDI = Carbon Emission Disclosure Index;

Dij = Disclosure Score for each GRI 305 indicator;

MXCQ = Maximum disclosure scores for this study is 7.

Table 2

Variables Measurements

Variables	Measurements	Data	Sources
Dependent variable			
Carbon Emission Disclosure	A disclosure index score based on a checklist derived from GRI 305.	Annual/Sustainability Report	Mansour et al., 2025; Issa et al., 2024; Amahalu et al., 2025.
Independent variables			
Board Independence (BIND)	Ratio of independent directors to the overall board size	Annual Report	Rahmawati et al., 2024; Wahyuni et al., 2023; Kim et al.,2023.
Board Gender Diversity (BGD)	Ratio of female board members to the overall board size	Annual Report	Uzochuckwu & Emmanuel, 2025; Sari & Hudaya, 2023; Gonenc & Krasnikova, 2022.
Board Nationality (BNAT)	Ratio of foreign directors to the overall board size	Annual Report	Chika & Widianingsih, 2024; Rahmawati et al., 2024.
Board Commitment (BCOMM)	Summation of the proportion of meeting attendance by each member (individual board member at board meetings) to total meetings held by the firm annually/board size.	Annual Report	Almaqtari et al., 2023; Sekarlangit & Wardhani, 2021.
Sustainability/Environment Committee (SUSCOM)	Dummy variable (1 if firm has a sustainability/environmental committees on the board, 0 otherwise.	Annual Report	Budianto et al., 2025; Lasmiati et al., 2025; Lina & Devyanti, 2024; Wei, 2024.
Control variables			
Return on Assets	Calculated as profit after tax divided by total assets	Annual Report	Alhares, 2025; Santoso et al., 2024; Cahyawati & Azizah, 2024.
Leverage (LEV)	Ratio of total liabilities to total assets	Annual Report	Dwiananda & Wirawati, 2025; Jaggi et al., 2021; Omaliko et al., 2021.
Green Performance (GPERF)	Dummy variable (value of 1 if the company has ISO 14001 Certification and 0 otherwise)	NGX	Jannah & Narsa, 2021.

Source: Authors Compilation (2026)

The following regression model is used to examine the impact of board characteristics on carbon emission disclosure:

$$\mathbf{CED_{it} = \beta_0 + \beta_1 BIND_{it} + \beta_2 BGD_{it} + \beta_3 BNAT_{it} + \beta_4 BCOMM_{it} + \beta_5 SUSCOM_{it} + \beta_6 ROA_{it} + \beta_7 LEV_{it} + \beta_8 GPERF_{it} + €_{it}}$$

β_0 denotes a constant, β_1-β_5 stands for coefficients of the explanatory variables, and β_6-β_8 stand for control variables coefficients. CED stands for carbon emission disclosure, BIND for board independence, BGD for board gender diversity, BNAT for board nationality, BCOMM for board commitment, ROA for profitability, LEV for leverage, GPERF for green performance, and € is for the error term.

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

The study presents the descriptive statistics of the variables in Table 3.

Table 3
Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ced	450	0.111	0.222	0.000	1.000
bind	450	0.177	0.157	0.000	0.667
bgd	450	0.197	0.145	0.000	0.667
bnat	450	0.200	0.211	0.000	0.714
bcomm	450	0.94	0.073	0.528	1.000
suscom	450	0.107	0.309	0.000	1.000
roa	450	0.029	0.160	-1.038	1.763
lev	450	0.653	0.267	0.194	2.478
gperf	450	0.198	0.399	0.000	1.000

Source: Authors Compilation (2026)

The average value for carbon emission disclosure is 0.111 (11.1% of maximum allowable disclosure), with minimum and highest values of 0 and 1, respectively. The standard deviation (SD) of 0.222 indicates moderate variation in carbon emission disclosure practices among the sampled manufacturing firms. The low mean score suggests that, on average, Nigerian listed manufacturing firms disclose only about 11.1% of the carbon-related information captured in the GRI 305-based disclosure index, demonstrating weak carbon emission disclosure practices in the sector.

The mean value of board independence (BIND) is 0.177, and its standard deviation is 0.157 and minimum and maximum values of 0 and 0.667, respectively. This indicates that, on average independent directors are about 17.7% of board membership which is below the one-third benchmark subsequently provided for independent non-executive directors applicable to public companies under section 275(1) of the Companies and Allied Matters Act (CAMA) 2020, as amended. Board gender diversity (BGD) has a mean of 0.197, a standard deviation of 0.145 and minimum and maximum values of 0 and 0.667. This implies that female directors represent, on average, about 19.7% of board composition, indicating slow but inadequate progress toward gender parity in corporate boardrooms. Board nationality (BNAT) has a mean value of 0.200 and a standard deviation of 0.211, with minimum and maximum

values of 0 and 0.714, respectively. This implies that foreign directors account for approximately 20% of board membership on average, suggesting a moderate level of international representation. Board commitment (BCOMM) has a high average value of 0.94 with a low standard deviation, and minimum and maximum values of 0.528 and 1, respectively. This demonstrates a high attendance rate to board meetings across the studied firms, implying that directors are generally devoted to attending board meetings. The dummy variable for sustainability/environmental committee (SUSCOM) has a mean of 0.107 and a standard deviation of 0.309, with minimum and maximum values of 0 and 1. This shows that about 10.7% of the sampled firms have established a dedicated sustainability or environmental committee on their boards, suggesting that such committees are still relatively uncommon among Nigerian manufacturing firms.

4.2 Correlation Analysis and Multicollinearity Tests

Table 4

Correlations Matrix

Variables	ced	bind	bgd	bnat	bcomm	suscom	roa	lev	gperf
ced	1.000								
bind	0.258	1.000							
bgd	0.279	0.320	1.000						
bnat	0.180	0.065	-0.087	1.000					
bcomm	0.184	0.157	0.006	0.060	1.000				
suscom	0.235	0.260	-0.024	0.081	0.051	1.000			
roa	0.044	0.162	0.110	0.055	0.021	-0.022	1.000		
lev	-0.073	-0.210	-0.007	-0.120	-0.087	0.050	-0.430	1.000	
gperf	0.322	0.073	0.178	0.098	0.152	0.100	0.087	-0.021	1.000

Source: Authors Compilation (2026)

Table 4 presents the pairwise correlation coefficients among all variables. All independent and control variables except leverage (LEV) exhibit positive correlations with carbon emission disclosure. Specifically, board independence (r = 0.258), board gender diversity (r = 0.279), board nationality (r = 0.180), board commitment (r = 0.184), and sustainability/environmental committee (r = 0.235) all show positive correlations with CED. Green performance also exhibits a relatively strong positive correlation with CED (r = 0.322). The correlation coefficients among the independent variables are all below the threshold of 0.8, suggesting the possible absence of multicollinearity. To further validate this, the Variance inflation factor (VIF) test was conducted, and the results are presented in Table 5. All VIF values are below 5, with a mean VIF of 1.174, confirming the absence of multicollinearity among the explanatory variables.

Table 5

Variance inflation factor

	VIF	1/VIF
bind	1.322	.757
bgd	1.202	.832
bnat	1.046	.956
bcomm	1.057	.946

	VIF	1/VIF
bsuscom	1.120	.893
roa	1.254	.797
lev	1.300	.769
gperf	1.087	.920
Mean VIF	1.174	

Source: Authors Compilation (2026)

TABLE 6. Pre-estimations

Test	F/Chi - Statistics	P-value
Hausman (1978) specification test.	15.770	0.046
Modified-Wald test for group-wise heteroskedasticity.	2.000	0.000
Wooldridge test for autocorrelation.	6.631	0.014

Source: Authors Compilation (2026)

The study applied Hausman test to find the optimum estimation technique between fixed and random effects model. The test gave a chi-square statistic of 15.77 with a p-value of 0.0458, which is significant at the 5% level. This finding implies that the fixed effects model is more suitable for this study. Further diagnostic tests were performed to test for the presence of heteroskedasticity and autocorrelation in the model. The Modifield-Wald test for group-wise heteroskedasticity produced a chi-square statistic of 2.000 with a p-value of 0.000, which implies the presence of heteroskedasticity. Similarly, the Wooldridge test for autocorrelation gave an F-statistic of 6.631 with a p-value of 0.0135, which confirmed the presence of autocorrelation in the panel data. The presence of heteroskedasticity and autocorrelation can produce biased and unreliable standard errors. To this end, the study addressed this issue by employing Panel-Corrected Standard Errors (PCSE) regression. Panel-Corrected Standard Errors (PCSE) were employed for the estimation of the model because the panel structure of the dataset may be associated with heteroscedasticity, serial correlation, autocorrelation and contemporaneous correlation across the firms. PCSE provides standard-error estimates that are corrected for the cross-sectional and temporal characteristics of panel data., thereby improving the reliability of statistical inference. The choice of PCSE was therefore considered appropriate for the balanced panel structure of the study.

Table 7

PCSE Regression

CED	Coef.	St.Err.	z-value	p-value
BIND	0.096	0.070	1.38	0.168
BGD	0.245	0.069	3.57	0.000
BNAT	0.136	0.032	4.19	0.000
BCOMM	0.176	0.102	1.73	0.084
SUSCOM	0.138	0.029	4.77	0.000
ROA	-0.038	0.043	-0.89	0.374
LEV	-0.043	0.026	-1.61	0.107
GPERF	0.125	0.023	5.50	0.000
Constant	-0.220	0.092	-2.391	0.017
Number of observations				450
R-Squared				0.2913
Chi-square				453.30
Prob > chi2				0.0000

Source: Authors Compilation (2026)

The PCSE results are presented in Table 7. The model has an R-squared value of 0.2913, indicating that the explanatory variables collectively account for approximately 29.13% of the variation in carbon emission disclosure among the sampled firms. The chi-square statistics of 453.30 is statistically significant at the 1% level ($p<0.0000$), which indicates that the explanatory variables jointly have a statistically significant relationship with carbon emission disclosure. The PCSE regression results above show that board independence has an insignificant impact on carbon emission disclosure ($\beta = 0.096$, $p = 0.168$). This finding suggests that the proportion of independent directors on the board does not affect decision to disclose carbon emission information among Nigerian listed manufacturing firms. The p-value is statistically insignificant, we fail to reject the Hypothesis that board independence has no significant impact on carbon emission disclosure. This result is inconsistent with the findings of Lahyani (2022) who found a significant positive effect of board independence on carbon emission disclosure among French listed companies, and the Nigerian studies of Amahalu et al. (2025), Ezekiel et al. (2024), and Joel et al. (2023), who each reported significant positive relationships.

However, these findings are consistent with other studies conducted by Mahentra et al. (2024), Suzana et al. (2023), Musa and Alqubaysi (2023), Sari and Hudaya (2023), and Randanu et al. (2022), who found no significant association between independent directors and carbon emission disclosure. This suggests that the existence of independent directors alone may not be enough to impact the environmental disclosure practices in Nigerian manufacturing firms. One possible explanation is that independent directors may focus primarily on financial oversight and regulatory compliance rather than environmental supporting issues. The insignificant relationship between board independence and carbon emission disclosure does not imply that Agency Theory is invalid. Rather, it indicates that the specific agency-theoretic expectation that greater board independence would enhance carbon emission disclosure is not empirically supported in the present sample. Agency Theory remains relevant to explaining the potential monitoring role of independent directors, However, the effectiveness of this mechanism may depend on institutional, firm-specific and contextual factors. Therefore, the

finding will be interpreted within the study's combined theoretical framework of Agency Theory, Stakeholder Theory and Resource Dependence Theory.

Board gender diversity has a positive and highly significant effect on carbon emission disclosure ($\beta = 0.245$, $p < 0.000$). This implies that firms with higher female representation on their boards disclose significantly more carbon emission information than firms with less gender-diverse boards. This result aligns with Resource Dependence Theory which suggest that female directors have better ethical orientation and stakeholder awareness. The p-value is significant, hence we reject the Hypothesis that board gender diversity has no significant impact on carbon emission disclosure. The result is consistent with the findings of Gonenc and Krasnikova (2022) that the proportion of female directors has a strong positive link with voluntary carbon emission disclosure. Similarly, board nationality positively and significantly impacts carbon emission disclosure ($\beta = 0.136$, $p < 0.001$). The positive coefficient suggests that firms with higher percentage of foreign nationals are more likely to disclose carbon emission information. Since the p-value is significant, we reject the Hypothesis that board nationality has no significant impact on carbon emission disclosure. The result is consistent with Kim and Lee (2023) findings that diverse national backgrounds may provide broader perspectives and experiences that can enhance the board's capacity to respond to environmental and stakeholder expectations but contradict Astuti and Setiany (2021) findings that board nationality has no significant effect on carbon emissions disclosure.

Board Commitment has a positive relationship with carbon emission ($\beta = 0.176$, $p = 0.084$). Although the result is statistically significant at the 10% level, it is not statistically significant at the 5% level. This suggests that board commitment provides relatively weak but positive evidence of an association with carbon emission disclosure under the study's 5% decision criterion. Therefore, we fail to reject the Hypothesis that board commitment has no significant impact on carbon emission disclosure.

Board sustainability committee has a positive and significant impact on carbon emission disclosure ($\beta = 0.138$, $p < 0.01$). The positive coefficient suggests that firms with sustainability committee are more likely to disclose carbon emission information. Since the p-value is significant, we reject the Hypothesis that board sustainability committee has no significant impact on carbon emission disclosure. The findings align with Resource Dependence Theory which suggest that presence of environmental committees enable firms to effectively engage and address stakeholders environmental concerns. The results is also consistent with Yahaya et al. (2022) findings that sustainability committees positively influence environmental information reporting. It also resonates with the European evidence provided by Khatri and Giskas (2025), who found that firms with dedicated sustainability committees produced significantly better disclosure quality, and Karaman et al. (2025), who documented that environmental committees reinforced the link between board composition and sustainable supply chain practices. However, the finding contradicts Adeleke et al. (2025), who found that the presence of a board sustainability committee did not significantly affect climate change actions among Nigerian listed firms.

5. CONCLUSION

Theoretically, the study contributes to the literature by providing sector-specific evidence on how different dimensions of board characteristics relate to carbon emission disclosures within the Nigerian manufacturing context. The findings suggest that the explanatory

relevance of board governance mechanism is not necessarily uniform across all board characteristics. This provides a more nuanced understanding of the combined relevance of Agency Theory, Stakeholder Theory and Resource Dependence Theory in explaining carbon emission disclosure. In particular, the findings demonstrate that empirical support for individual theoretical propositions may vary according to the specific board characteristics and institutional context examined.

Practically, the study provides evidence that may assist corporate boards , regulators and other stakeholders in strengthening governance mechanisms associated with carbon emission disclosure.

Therefore, the study extends the existing Nigerian literature by providing sector-specific evidence on the relationship between board characteristics and carbon emission disclosure among listed manufacturing firms. While previous Nigerian studies have examined related relationships in other sectoral contexts, particularly oil and gas sector, the present study demonstrates that the implications of board characteristics for carbon emission disclosure should also be examined within the manufacturing environment. The study contributes to the literature by providing evidence from a distinct sectoral context, using a GRI 305 - based disclosure measure and a ten-year panel covering 2015 - 2024. The findings also have implications for corporate boards and regulators seeking to strengthen governance mechanisms among Nigerian manufacturing firms.

6. RECOMMENDATIONS

In light of the findings, the study recommends greater gender and nationality diversity on corporate boards and enhanced effectiveness of sustainability/environmental committees to promote improved carbon emission disclosure among listed manufacturing firms in Nigeria.

Although this study provides some contributions, it is important to recognize some limitations that might guide future research efforts. This study focused exclusively on listed manufacturing firms in Nigeria. Therefore, the outcomes may limit the generalization of the results to firms operating in other sectors. Future research could expand the scope to other sectors, incorporating additional governance variables, and investigate the moderating or mediating effects of environmental regulation, sustainability assurance, and ESG performance.

AI DISCLOSURE STATEMENT

In the preparation of this manuscript, generative artificial intelligence (AI) tools, including OpenAI ChatGPT, were used solely for language refinement and editorial assistance. All AI-assisted material was critically reviewed and verified by the authors. The authors retain full responsibility for the accuracy, originality, integrity, and final content of the manuscript.

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