DOES SCOPE-BASED CARBON DISCLOSURE DRIVE SHAREHOLDERS' VALUE? A MULTIVARIATE ANALYSIS OF NIGERIAN FIRMS

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Abstract
This study investigates the impact of scope-based carbon emissions (Scope 1, Scope 2, and Scope 3) and sustainability reporting on the market valuation of firms listed on the Nigerian Exchange Limited (NGX). Using multivariate regression on panel data covering nine firms from 2012 to 2023, the findings reveal that Scope 2 emissions have a statistically significant positive effect on firm value, measured by Tobin's Q, indicating investor sensitivity to indirect emissions linked to operational efficiency. In contrast, Scope 1 and Scope 3 emissions, as well as sustainability reporting, showed no significant influence, suggesting challenges related to the credibility or materiality of these disclosures in Nigeria. The results reveal the need for improved standardization and verification of emissions and sustainability disclosures to enhance their relevance for investors.

Key words: *Carbon emissions, Firm value, Scope 2, Sustainability reporting.*

Introduction

In recent years, carbon emission disclosure has gained prominence in global corporate reporting as investors, regulators, and stakeholders intensify demands for transparency in environmental performance. The rising emphasis on Environmental, Social, and Governance (ESG) metrics, particularly carbon disclosures, reflects a growing consensus that climate-related risks are financially material (Kotsantonis & Serafeim, 2020). Consequently, firms worldwide are expected to adopt credible frameworks for carbon accounting, such as the Greenhouse Gas (GHG) Protocol, which classifies emissions into Scope 1 (direct), Scope 2 (indirect from energy), and Scope 3 (indirect across the value chain). These categories offer nuanced insights into a firms' environmental footprint and operational sustainability (Kramarz et al., 2023). Investors now increasingly factor ESG performance into capital allocation decisions, especially in carbon-intensive sectors, (Fatemi, Glaum, & Kaiser, 2022). Empirical evidence suggests that transparent climate-related disclosures can enhance firm value, reduce capital costs, and strengthen long-term investor relations (Khan, Serafeim, & Yoon,

2022). Yet, a critical question remains: which dimensions of carbon disclosure matter most to investors? While Scope 1 emissions are easily traceable and tied to operational efficiency, Scope 2 and Scope 3 emissions capture broader sustainability practices and supply chain risks—making them potentially more relevant to ESG-sensitive investors (Pfeifer et al., 2023). This question is particularly salient in emerging markets like Nigeria, where corporate ESG disclosures remain inconsistent, unaudited, or fragmented. Nigeria presents a unique context due to its status as an oil-producing economy with growing ESG adoption but limited regulatory enforcement in climate reporting (Onyali & Okafor, 2021). Many Nigerian firms voluntarily disclose emissions data, yet it remains unclear which emission scopes are most value-relevant to capital markets. Given rising investors' scrutiny globally, it is critical to understand whether disclosure of Scope 1, 2, or 3 emissions differentially influences firm valuation. This paper is therefore an attempt to investigate the lack of empirical clarity on whether Nigerian investors are able to differentiate between types of carbon emission disclosures when assessing firm's value. Despite the proliferation of ESG metrics, scant evidence exists on the comparative materiality of Scope-based disclosures in frontier economies.

Objectives

To this end, the specific objectives of this study is to empirically test whether *Scope 1, Scope 2, or Scope 3 carbon emissions disclosures significantly influence the market value of listed Nigerian firms?*

The rest of the paper is organized as follows: Section 2 reviews relevant literature; Section 3 focuses on methodology and model specification, section 4 deals with data analysis and interpretation of results; and Section 5 conclusion.

Literature Review

Theoretical Framework

This study is anchored in Stakeholder Theory (Freeman, 1984) and Legitimacy Theory (Dowling & Pfeffer, 1975; further developed by Suchman, 1995). Stakeholder Theory emphasizes the importance of balancing the needs of diverse stakeholder groups, while Legitimacy Theory posits that organizations seek to align their activities with societal expectations to secure continued support and survival. The theories provide valuable lenses for understanding why firms engage in carbon disclosure and how these actions influence shareholder perceptions. Stakeholder theory asserts that companies should be accountable not only to shareholders but also to other stakeholders—such as customers, regulators, and environmental advocates—whose interests affect or are affected by corporate activities (Freeman et al., 2021). Under this theory, carbon emission disclosures are a strategic response to growing environmental expectations and investor

demand for transparency, which in turn can influence firm value (Lys et al., 2022).

Legitimacy theory complements this view by positing that firms disclose environmental information to align with social norms and maintain legitimacy in the eyes of key stakeholders. Especially in carbon-intensive sectors, firms may use disclosure as a tool to justify their existence and mitigate reputational risk (Mio et al., 2023). These theoretical perspectives jointly imply that environmental disclosures—particularly when credible and standardized—can affect investor decisions and, by extension, market valuation.

Empirical Review

Scope 1 Emissions and Firm Value

Scope 1 emissions refer to direct greenhouse gas emissions from a firm's owned or controlled operations. The empirical literature offers mixed results regarding their effect on firm valuation. Okike and Nwachukwu (2024) found that in the Nigerian oil and gas industry, robust and verified Scope 1 disclosures were positively associated with market value. Their study emphasized the role of governance structures in enhancing the credibility of such disclosures. However, other studies report limited valuation effects. For example, Liesen et al. (2023) argued that Scope 1 disclosures in many emerging markets often lack comparability and rigor, which diminishes their informational value. Onoh et al. (2022) observed that vague or inconsistent reporting in Nigeria leads to weak investor confidence in Scope 1 data. These discrepancies may reflect sectoral differences, reporting quality, or investor sophistication. Given the absence of a clear consensus in the literature, this study examines the following hypothesis:

H_{01}: *Scope 1 carbon emission disclosure has no significant effect on the firm value of listed firms in Nigeria.*

Scope 2 Emissions and Firm Value

Scope 2 emissions represent indirect emissions from the consumption of purchased electricity, steam, heating, and cooling. These emissions often reflect the energy efficiency of a firm's operations and its transition toward sustainable practices.

Aguguom (2024) found that manufacturing firms in Nigeria that disclosed Scope 2 emissions—particularly those linking the data to energy-saving initiatives—enjoyed stronger investor confidence and valuation premiums. Similarly, Yuan and Bao (2025), using data from emerging Asian markets, showed that emission intensity metrics (e.g., Scope 2 per unit revenue) had significant positive effects on market capitalization, especially in energy-intensive industries.

Fatica and Panzica (2022) confirmed that Scope 2 disclosures help lower the cost of capital in European markets, while Li (2023) found similar valuation effects in Latin America. These findings suggest that Scope 2 emissions may be perceived by investors as signals of operational scale or future competitiveness. Based on this literature, the study tests the second hypothesis:

H_{02}: *Scope 2 carbon emission disclosure has no significant effect on the firm value of listed firms in Nigeria.*

Scope 3 Emissions and Firm Value

Scope 3 emissions encompass all other indirect emissions that occur in a company's value chain, including upstream activities (e.g., supply chain) and downstream impacts (e.g., product usage and disposal). Although difficult to measure, Scope 3 emissions often make up the largest portion of a firm's carbon footprint.

Tang et al. (2025) demonstrated that firms with comprehensive Scope 3 disclosures experienced stronger stock performance due to enhanced risk signaling and stakeholder engagement. Likewise, Emovon and Ogbonmwan (2025) reported that Nigerian oil and gas firms that disclosed Scope 3 emissions—especially when aligned with Sustainable Development Goals (SDGs)—benefited from positive investor reactions.

On the other hand, Onoh et al. (2022) argued that many Nigerian firms either omit or inconsistently report Scope 3 emissions, limiting the disclosures' credibility and market relevance. As such, Scope 3's influence on firm value is likely dependent on both the quality and context of the disclosure. To assess this relationship in the Nigerian context, the following hypothesis is proposed:

H_{03}: *Scope 3 carbon emission disclosure has no significant effect on the firm value of listed firms in Nigeria.*

Sustainability Financial Reporting and Firm Value

Sustainability financial reporting refers to the integration of environmental, social, and governance (ESG) information into corporate financial reporting, often in line with frameworks like the Global Reporting Initiative (GRI), IFRS S1 and S2, or Integrated Reporting (<IR>).

Easton et al. (2025) found that firms aligning their disclosures with international sustainability frameworks reported higher investor confidence and improved market valuation. Emovon and Ogbonmwan (2025) also observed that firms reporting SDG-aligned sustainability data in Nigeria enjoyed enhanced financial performance and capital access. However, the impact of sustainability reporting depends largely on

credibility, standardization, and third-party assurance. Aguguom (2024) cautioned that many Nigerian firms publish unverified ESG reports that lack consistency, which undermines their perceived value to investors. Fiechter et al. (2021) emphasized that for sustainability reporting to be effective, it must be material, auditable, and embedded in strategic decision-making. This leads to the fourth hypothesis:

H_{04}: *Sustainability financial reporting has no significant effect on the firm value of listed firms in Nigeria.*

Methodology

This study adopts a quantitative, ex-post facto research design, appropriate for analyzing the historical relationship between carbon emission disclosures, sustainability reporting, and firm value without manipulating any variables. The ex-post facto approach is well-suited for this investigation, as it relies on archival data that reflect real-world corporate behavior over time. The study population includes 151 firms listed on the Nigerian Exchange Group (NGX) across major sectors such as oil and gas, manufacturing, consumer goods, and financial services. A purposive sampling technique was employed to select firms that consistently disclosed Scope 1, Scope 2, and Scope 3 carbon emissions, along with sustainability-related information, from 2012 to 2023. The final sample consists of nine firms, selected based on their verifiable disclosures, relevance to high-emission sectors, and availability of financial data.

Data were obtained from secondary sources, including annual reports, sustainability/ESG reports, firm websites, and the NGX platform. Where applicable, disclosures were cross-validated using third-party databases such as the Carbon Disclosure Project (CDP). The dependent variables are Tobin's Q (TOBINQ) and Market Capitalization (MC), used as indicators of firm value. Independent variables include Scope 1, 2, and 3 emissions (normalized by revenue), a sustainability reporting dummy (SRS), firm size (log of total assets), leverage (debt-to-equity ratio), and profitability (return on assets or ROA). The study uses Multivariate Regression (MVREG) to simultaneously model the impact of carbon disclosure and sustainability reporting on two measures of firm value (TOBINQ and MC). This method is chosen because firm value is a multi-dimensional construct that cannot be adequately captured by a single proxy. Tobin's Q reflects investors' perception of market-to-book value, while Market Capitalization captures real-time market value and scale. Modeling these jointly improves statistical efficiency, allows for the control of error term correlations between equations, and provides a more comprehensive analysis of how environmental variables impact different dimensions of firm valuation.

The mvreg model is specified as follows:

$MC_{it}, TOBINQ_{it} = \beta_0 + \beta_1 S1_{it} + \beta_2 S2_{it} + \beta_3 S3_{it} + \beta_4 SRS_{it} + \beta_5 FS_{it} + \beta_6 LEV_{it} + \beta_7 ROA_{it} + \mu_i + \tau_t + \varepsilon_{it}$

Where:

MC = Firm value (MC)

TOBINQ = Firm value (Tobin Q)

S1 = Scope 1 emissions per unit of revenue (Emission_Scope1 / Revenue)

S2 = Scope 2 emissions per unit of revenue (Emission_Scope2 / Revenue)

S3 = Scope 3 emissions per unit of revenue (Emission_Scope3 / Revenue)

SRS = Sustainability reporting dummy (1 = reporting aligned with SDGs/GRI/IFRS, 0 = otherwise)

FS = Firm size (natural log of total assets)

LEV = Leverage (total debt / total equity)

ROA = Profitability (return on assets or ROA)

ε = Error term

Estimation was conducted with STATA 17 using the mvreg command for multivariate regression analysis. Before running the model, key diagnostic tests were performed to ensure robustness. These included the Shapiro–Wilk test for normality, VIF for multicollinearity, the Breusch–Pagan/Cook–Weisberg test for heteroskedasticity, and the Ramsey RESET test to check for model misspecification. The diagnostics confirmed the model's suitability for analysis. Where necessary, robust standard errors were applied to correct for non-constant variance and autocorrelation. These diagnostics enhance the validity and reliability of the model, ensuring robust inference. By modeling TOBINQ and MC simultaneously, the multivariate regression approach offers a more nuanced understanding of how carbon emissions and sustainability strategies influence both the perceived and actual market value of Nigerian firms.

Results and Interpretation

Descriptive Statistics

The descriptive statistics presented offer insights into the distribution and characteristics of the variables used in the multivariate analysis.

Table 1: Descriptive Statistics Table

Variable	Mean	Median	Max	Min	Std Dev (SD)	N
MC	19	19	22	16	2	29
TOBINQ	1.4	0.82	3.8	0.63	0.89	29
S1	0.0019	0.0002	0.014	4.40E-05	0.0035	29
S2	0.00031	0.000072	0.0024	0.00000019	0.00058	27

S3	0.00044	0.00011	0.0025	0.00000017	0.00073	24
SRS	0.76	1	1	0	0.44	29
FS	21	21	22	16	1.6	29
LEV	73	77	91	45	17	29
ROA	6.3	2.9	16	-12	6.9	29

Source: Researchers' Computation (2025) using Stata 17

The dependent variables, Market Capitalization (MC) and Tobin's Q (TOBINQ), have mean values of 19 and 1.4, respectively. While MC is relatively symmetrical around the median (19), TOBINQ is right-skewed, with a median of 0.82 and a maximum of 3.8, indicating that a few firms have notably high market valuations. For the independent variables, Scope 1 (S1) emissions have a mean of 0.0019, though the median is just 0.0002, suggesting a highly skewed distribution with most firms reporting minimal direct emissions. Scope 2 (S2) and Scope 3 (S3) emissions follow similar patterns, with very low median values compared to their maximums, further indicating skewness and the presence of outliers—likely due to differences in operational scale and disclosure intensity across firms.

The Sustainability Reporting Score (SRS) has a mean of 0.76 and a median of 1, reflecting that the majority of firms in the sample adhere to recognized sustainability reporting frameworks. The Firm Size (FS) variable, measured as the natural log of total assets, has a relatively tight range (mean = 21, SD = 1.6), while Leverage (LEV) displays a broader distribution with a mean of 73 and a standard deviation of 17, indicating varied capital structures across firms.

Finally, Return on Assets (ROA) ranges from -12 to 16, with a mean of 6.3 and a median of 2.9, suggesting profitability differs widely within the sample, and a few firms are operating at a loss. Overall, the data exhibit substantial heterogeneity across key financial and sustainability metrics, highlighting the importance of robust statistical modeling in the subsequent analysis.

Diagnostic Tests

Overview of Diagnostic Procedures

Prior to estimating the multivariate regression model, a series of diagnostic tests were conducted to verify the validity of underlying statistical assumptions. These included checks for normality (via Shapiro–Wilk and Skewness/Kurtosis tests), multicollinearity (Variance Inflation Factor), heteroskedasticity (Breusch–Pagan/Cook–Weisberg test), and model specification (Ramsey RESET test). Additional multivariate diagnostics, such as Hotelling's T^2, Likelihood Ratio (LR) tests for covariance and correlation structures, and the Doornik–Hansen test for multivariate normality, were employed to assess the appropriateness of applying multivariate regression. These procedures

ensured robustness, improved model accuracy, and confirmed the statistical suitability of the data for the analysis.

Univariate and Bivariate Assumption Checks

Before proceeding with multivariate regression, univariate and bivariate diagnostics were conducted to ensure that the data conformed to essential statistical assumptions. These checks involved evaluating normality, variable dispersion, and pairwise correlations to validate the suitability of the dataset for robust estimation.

Normality Tests

To ensure the validity of regression estimates, the assumption of normality was tested for all variables. Two complementary approaches were employed: the Skewness–Kurtosis test and the Shapiro–Wilk W test. These tests assess whether the distribution of each variable deviates significantly from a normal distribution, which is a critical assumption for inference in classical linear models.

Table 2: Normality Tests Using Skewness–Kurtosis and Shapiro–Wilk Methods

Variable	Obs	Pr(Skewness)	Pr(Kurtosis)	adj chi2(2)	Prob>chi2	W	Prob>z
MC	29	0.7960	0.0003	10.47	0.0053	0.91069	0.01783
TOBINQ	29	0.0091	0.3377	6.91	0.0317	0.7921	6.00E-05
S1	29	0.0000	0.0037	18.27	0.0001	0.60129	0.0000
S2	27	0.0000	0.0005	22.16	0.0000	0.58542	0.0000
S3	24	0.0002	0.014	14.55	0.0007	0.62225	0.0000
SRS	29	0.0066	0.7174	6.75	0.0342	0.89262	0.00655
FS	29	0.0003	0.014	14.32	0.0008	0.77738	3.00E-05
LEV	29	0.5410	0.0000	18.94	0.0001	0.82505	0.00024
ROA	29	0.3149	0.8602	1.11	0.5737	0.90172	0.01078

Source: Researchers' Computation (2025) using Stata 17

Results presented in Table 2 reveal that several variables significantly violated the normality assumption. Specifically, Scope 1 (S1), Scope 2 (S2), and Scope 3 (S3) emissions, as well as firm size (FS) and leverage (LEV), showed adjusted chi-square p-values well below the 0.05 threshold in the Skewness–Kurtosis test. These findings were corroborated by the Shapiro–Wilk W test, which also produced statistically significant results ($p < 0.05$) for the same variables, indicating a rejection of the null hypothesis of normality.

Market capitalization (MC) and Tobin's Q (TOBINQ) also displayed departures from normality in at least one of the tests. In contrast, return on assets (ROA) demonstrated no significant violation of normality under either test, while sustainability reporting

status (SRS) showed marginal evidence of normality deviation. The prevalence of non-normal distributions across key independent and dependent variables suggests that the use of conventional ordinary least squares (OLS) methods may lead to biased or inefficient estimates. Consequently, this justifies the use of robust estimation techniques, such as multivariate regression with robust standard errors, which are less sensitive to violations of distributional assumptions.

Correlation Analysis

To explore the bivariate relationships among the study variables and to assess potential multicollinearity prior to regression analysis, a Pearson correlation matrix was computed and is presented in Table 3. The analysis provides initial insights into the strength and direction of linear associations, offering a basis for evaluating consistency with theoretical expectations.

Table 3: Pearson Correlation Matrix

	MC	**TOBINQ**	**S1**	**S2**	**S3**	**SRS**	**FS**	**LEV**	**ROA**
MC	1								
TOBINQ	0.5897	1							
S1	0.2626	0.0005	1						
S2	0.4909	0.8356	0.1029	1					
S3	0.5799	0.8338	0.0417	0.8323	1				
SRS	0.4081	0.0003	0.1765	-0.0729	-0.0103	1			
FS	0.5562	-0.1513	0.1579	0.0414	0.0788	0.3539	1		
LEV	-0.2076	-0.2805	-0.6024	-0.2913	-0.1728	-0.0343	0.3268	1	
ROA	0.2373	0.6622	-0.2466	0.4774	0.5483	0.0668	-0.4661	-0.2352	1

Source: Researchers' Computation (2025) using Stata 17

As shown in Table 3, TOBINQ, a proxy for firm value—exhibits strong positive correlations with Scope 2 (r = 0.836) and Scope 3 (r = 0.834) emissions, suggesting that higher indirect emissions may be associated with higher market valuation, possibly reflecting the operational scale or energy intensity of firms. A similar pattern is observed with MC, which also correlates positively with Scope 2 (r = 0.491) and Scope 3 (r = 0.580). These results preliminarily support the view that investors may respond more strongly to indirect emissions than to direct ones.

Scope 1 emissions demonstrate very weak or near-zero correlation with TOBINQ (r = 0.001), aligning with previous findings in emerging markets where direct emissions are less systematically disclosed or priced by investors. Additionally, firm size (FS) shows

a moderate positive correlation with MC (r = 0.556), as expected, but a weak negative correlation with TOBINQ (r = -0.151).

From a multicollinearity standpoint, notable inter-variable correlations are observed between Scope 2 and Scope 3 (r = 0.832), indicating possible redundancy in explanatory power. Furthermore, leverage (LEV) is negatively correlated with Scope 1 (r = -0.602), which may imply that firms with higher direct emissions are less reliant on debt, possibly due to risk aversion from lenders. Although Pearson correlations alone do not confirm multicollinearity, the strength of associations—particularly between the emission scopes—warrants further investigation using variance inflation factors (VIF) to formally assess collinearity in the multivariate model. Overall, the correlation results help validate the inclusion of specific predictors and guide interpretation of regression outputs.

Regression Assumption Diagnostics

This section presents diagnostic tests conducted to verify the core assumptions underlying multivariate regression models. Specifically, the analysis assesses multicollinearity, heteroskedasticity, model specification, and residual normality to ensure the robustness and validity of coefficient estimates and inference.

Multicollinearity Diagnostics

Multicollinearity diagnostics were conducted to assess the degree of linear interdependence among the independent variables in the MC and TOBINQ models. This was done using the Variance Inflation Factor (VIF), with results summarized in Table 4.

Table 4 : Summary of Diagnostic Tests for MC and TOBINQ Models

Test Type	MC Model Result	TOBINQ Model Result
Multicollinearity (Mean VIF)	Mean VIF = 2.94	Mean VIF = 2.94
Highest VIF Variables	S3 (4.18), S2 (3.69), ROA (3.36)	S3 (4.18), S2 (3.69), ROA (3.36)

Source: Researchers' Computation (2025) using Stata 17

The mean VIF for both models was 2.94, well below the commonly used threshold of 10, suggesting that multicollinearity is not severe overall. However, individual VIF values reveal potential concerns: Scope 3 emissions (VIF = 4.18), Scope 2 emissions (VIF = 3.69), and ROA (VIF = 3.36) consistently exhibited the highest VIF scores across both models. These values approach the moderate multicollinearity range (VIF > 3), indicating the possibility of overlapping explanatory power, particularly among the emission scopes. While these levels do not necessitate immediate corrective action, they highlight the importance of cautious interpretation of coefficient estimates,

especially for Scope 2 and Scope 3 emissions. The results affirm the decision to employ multivariate regression techniques capable of accounting for inter-variable relationships.

Heteroskedasticity Test

To assess the assumption of constant variance in the error terms, the Breusch–Pagan/Cook–Weisberg test for heteroskedasticity was applied to both the MC and TOBINQ regression models.

Table 5: Summary of Diagnostic Tests for MC and TOBINQ Models

Test Type	MC Model Result	TOBINQ Model Result
Heteroskedasticity Test	$\chi^2(1) = 5.75$, p = 0.0165	$\chi^2(1) = 8.20$, p = 0.0042

Source: Researchers' Computation (2025) using Stata 17

The results, presented in Table 5, indicate statistically significant heteroskedasticity in both models: MC ($\chi^2(1) = 5.75$, $p = 0.0165$) and TOBINQ ($\chi^2(1) = 8.20$, $p = 0.0042$). These findings reject the null hypothesis of homoscedasticity at the 5% significance level, suggesting that the variance of the residuals is not constant across observations. This violates a key assumption of ordinary least squares (OLS) regression and may lead to inefficient estimates and biased standard errors if unaddressed. In response, robust standard errors were employed in the multivariate regression analysis to mitigate the effects of heteroskedasticity and ensure valid inference.

Model Specification Test

To verify whether the regression models were correctly specified and did not omit relevant variables or include irrelevant ones, the Ramsey RESET (Regression Specification Error Test) was applied to both the MC and TOBINQ models.

Table 6: Summary of Diagnostic Tests for MC and TOBINQ Models

Test Type	MC Model Result	TOBINQ Model Result
Model Specification (RESET Test)	F(3,13) = 1.14, p = 0.3686	F(3,13) = 0.36, p = 0.7826

Source: Researchers' Computation (2025) using Stata 17

As presented in Table 6, the results indicate no evidence of model misspecification: MC model ($F(3,13) = 1.14$, $p = 0.3686$) and TOBINQ model ($F(3,13) = 0.36$, $p = 0.7826$). In both cases, the p-values exceed the conventional 0.05 threshold, supporting the null hypothesis that the functional form of the models is correctly specified. This confirms that the included predictors and transformations are appropriate and that there is no need to augment the models with higher-order or omitted nonlinear terms. Thus, the models are deemed structurally adequate for multivariate regression analysis, reinforcing the validity of the estimated coefficients and inference drawn.

Multivariate Justification

To strengthen the analytical framework, additional tests were conducted to justify the use of multivariate regression. These include tests for equality of means (Hotelling's T^2), the structure of the covariance and correlation matrices, and multivariate normality. Significant results across these diagnostics confirm the presence of interdependencies among variables, heterogeneity in disclosure practices, and non-normality—thereby validating the application of a multivariate estimation technique (e.g., mvreg) over separate univariate regressions.

Equality of Means Test (Hotelling's T^2)

To assess whether the mean values of the dependent and independent variables significantly differ across the modelled equations, Hotelling's T^2 test was employed.

Table 7: Hotelling's T^2 Test of Equality of Means

Statistic	Value
Hotelling's T^2	7,228.88
Hotelling's F (8,16)	628.60
Prob > F	0.0000

Source: Researchers' Computation (2025) using Stata 17

As shown in Table 7, the results yielded a Hotelling's T^2 statistic of 7,228.88, with an associated F-statistic of 628.60 ($p < 0.0001$), indicating a statistically significant difference in group means. This result confirms that the explanatory variables jointly contribute to distinguishing between the two equations (MC and TOBINQ), thereby justifying the use of a multivariate framework. It further suggests that the responses of the dependent variables to the predictors are not homogeneous, warranting separate interpretation of the two models within the multivariate analysis.

Test of Covariance Matrix Diagonality

The Likelihood Ratio Test was conducted to examine whether the covariance matrix of the residuals is diagonal—an assumption that, if violated, would suggest interdependence among the error terms across equations.

Table 8: Likelihood Ratio Test of Diagonal Covariance Matrix

Test Description	Statistic
Adjusted Likelihood Ratio Chi^2 (df=36)	155.79
Prob > Chi^2	0.0000

Source: Researchers' Computation (2025) using Stata 17

As shown in Table 8, the adjusted likelihood ratio chi-square statistic is 155.79 with 36 degrees of freedom, and the associated p-value is < 0.0001. This result rejects the null hypothesis of a diagonal covariance matrix, indicating that the error terms across the MC and TOBINQ equations are correlated. Consequently, this validates the use of multivariate regression (mvreg), as it accounts for the non-independence of disturbances across multiple dependent variables, thereby improving efficiency in estimation and inference.

Correlation Structure Test

To evaluate whether all pairwise correlations among the study variables are equal—known as compound symmetry—the Lawley Chi-square test was applied.

Table 10: Lawley Test of Compound Symmetry in Correlation Matrix

Test Description	Statistic
Lawley Chi-square (df = 35)	118.59
Prob > Chi-square	0.0000

Source: Researchers' Computation (2025) using Stata 17

As presented in Table 10, the test yielded a Chi-square statistic of 118.59 with 35 degrees of freedom and a p-value of 0.0000. This highly significant result leads to the rejection of the null hypothesis of equal correlations across variables. The implication is that the correlation structure is heterogeneous, thus supporting the appropriateness of a multivariate analytical framework. The observed inequality in inter-variable relationships further justifies the use of multivariate regression models that can account for correlated disturbances and interdependencies in the data.

Multivariate Normality Test

To assess whether the joint distribution of the variables satisfies the assumption of multivariate normality, the Doornik–Hansen test was employed.

Table 11: Doornik–Hansen Test for Multivariate Normality

Test Description	Statistic
Doornik–Hansen Chi-square (df=18)	151.326
Prob > Chi-square	0.0000

Source: Researchers' Computation (2025) using Stata 17

As presented in Table 11, the test yielded a chi-square statistic of 151.326 with 18 degrees of freedom, and a p-value of < 0.0001. This result provides strong evidence against the null hypothesis of multivariate normality. The rejection of normality reinforces the earlier univariate findings and justifies the application of robust statistical techniques in the multivariate analysis to ensure valid inference despite distributional irregularities.

Equality of Disclosure Means

To assess whether the mean values of the carbon disclosure variables, Scope 1 (S1), Scope 2 (S2), Scope 3 (S3), and the Sustainability Reporting Score (SRS) differ significantly across firms, a Hotelling's T^2 test was conducted

Table 12: Test of Equality of Means for Carbon Disclosure and Sustainability Reporting Variables

Test	Statistic
Hotelling's T^2	331.61
Hotelling's F (3, 471)	110.07
Prob > F	0.0000

Source: Researchers' Computation (2025) using Stata 17

As shown in Table 12, the test yielded a Hotelling's T^2 statistic of 331.61, corresponding to an F-statistic of 110.07 with degrees of freedom (3, 471) and a p-value of 0.0000. This result is statistically significant at the 1% level, leading to the rejection of the null hypothesis of equal means across the four disclosure variables.

The finding confirms that there is substantial variation in the levels of carbon disclosure and sustainability reporting among Nigerian listed firms. These differences may reflect disparities in industry practices, resource availability, regulatory compliance, or strategic ESG orientation. The significant inequality in mean values further supports the need for multivariate analysis to capture the distinct influence of each disclosure dimension on firm value.

Post-Estimation Diagnostics

Post-estimation diagnostic tests were conducted to assess the reliability and validity of the multivariate regression results. These included normality tests on residuals (Skewness/Kurtosis) and cross-equation equality tests to determine whether carbon disclosure variables exert differential effects on market-based (TOBINQ) versus book-based (MC) firm valuation. Additionally, a residual correlation matrix was examined to detect lingering multicollinearity or inter-variable dependencies. The findings from these tests support the robustness of the model while highlighting subtle variations in how carbon disclosures influence different valuation metrics.

Normality of Residuals

To validate the assumptions underlying the multivariate regression models for disclosure variables, the Skewness/Kurtosis test for normality was conducted on the residuals of Scope 1 (reS1), Scope 2 (reS2), Scope 3 (reS3), and Sustainability Reporting Score (reSRS).

Table 13: Skewness/Kurtosis Tests for Normality of Residuals (reS1, reS2, reS3, reSRS)

Residual	Obs	Pr(Skewness)	Pr(Kurtosis)	adj $chi^2(2)$	Prob > chi^2
reS1	24	0.0033	0.0009	14.70	0.0006
reS2	24	0.0033	0.0009	14.70	0.0006
reS3	24	0.0033	0.0009	14.70	0.0006
reSRS	24	0.0033	0.0009	14.70	0.0006

Source: Researchers' Computation (2025) using Stata 17

As shown in Table 13, all four residuals yielded identical results: adjusted chi-square = 14.70, with a corresponding p-value of 0.0006. Additionally, both skewness and kurtosis components were significant (Pr(Skewness) = 0.0033; Pr(Kurtosis) = 0.0009), indicating deviation from normality across all residual distributions.

These statistically significant results reject the null hypothesis of normality at the 1% level for each residual term. The implications are twofold: (i) standard OLS assumptions may be violated, and (ii) the use of robust or generalized estimation techniques is warranted to ensure valid inference and mitigate the effects of non-normal error distributions. This diagnostic reinforces the study's methodological approach in adopting robust standard errors and multivariate estimation frameworks, particularly given the complexities inherent in carbon disclosure data.

Equality of Coefficients Across Equations

To assess whether the explanatory variables exert significantly different effects on market capitalization (MC) and Tobin's Q (TOBINQ), a series of cross-equation coefficient equality tests were performed. These tests compare the coefficients of each independent variable across the two dependent variable models estimated via multivariate regression.

Table 14: Cross-Equation Equality Tests of Coefficients (MC vs. TOBINQ)

Tested Equality	F (1, 16)	Prob > F
[TOBINQ]S1 = [MC]S1	0.04	0.8490
[TOBINQ]S2 = [MC]S2	4.37	0.0530
[TOBINQ]S3 = [MC]S3	0.58	0.4570
[TOBINQ]SRS = [MC]SRS	0.16	0.6983

Source: Researchers' Computation (2025) using Stata 17

As shown in Table 14, the null hypotheses of equal coefficients were not rejected for Scope 1 emissions (S1), Scope 3 emissions (S3), and the Sustainability Reporting Score (SRS). The p-values for these tests—0.8490, 0.4570, and 0.6983, respectively—indicate no statistically significant differences in their effects across the MC and TOBINQ equations. However, for Scope 2 emissions (S2), the F-statistic of 4.37 with

a marginal p-value of 0.0530 suggests a near-significant difference at the 5% level. This result implies that S2 may exert a more pronounced influence on market-based valuation (TOBINQ) compared to book-based valuation (MC), highlighting the possibility that investors respond more strongly to indirect emissions related to operational energy use.

These findings underscore the relevance of evaluating carbon disclosure effects across multiple dimensions of firm value. In particular, the differentiated impact of Scope 2 emissions warrants further attention in both research and practice, especially given its strong statistical and economic significance in valuation models.

Residual Correlation Matrix

To further validate the structure of the multivariate regression model and assess remaining interdependencies after accounting for fixed effects, a residual correlation matrix was constructed (see Table 4.15). The matrix displays pairwise correlations among residualized variables—i.e., variables purged of time and country effects—to isolate within-firm variation.

Table 15: Correlation Matrix of Residual Variables

Variable	rMC	rTOBINQ	S1	S2	S3	SRS	FS	LEV	ROA
rMC	1								
rTOBINQ	1	1							
S1	0.0000	0.0000	1						
S2	0.0000	0.0000	0.103	1					
S3	0.0000	0.0000	0.042	0.832	1				
SRS	0.0000	0.0000	0.177	-0.073	-0.01	1			
FS	0.0000	0.0000	0.158	0.041	0.079	0.354	1		
LEV	0.0000	0.0000	-0.602	-0.291	-0.173	-0.034	0.327	1	
ROA	0.0000	0.0000	-0.247	0.477	0.548	0.067	-0.466	-0.235	1

Source: Researchers' Computation (2025) using Stata 17

Table 15 presents the correlation matrix of residualized variables, which accounts for time and country fixed effects to isolate within-firm variation. The residual correlations reveal several noteworthy patterns that further validate the multivariate structure of the model. Notably, Scope 2 and Scope 3 emissions remain highly correlated (r = 0.832) even after adjusting for external influences, suggesting a common underlying driver—such as operational scale or supply chain intensity—linking these emission categories. Additionally, Return on Assets (ROA) maintains moderate to strong positive correlations with both Scope 2 (r = 0.477) and Scope 3 (r = 0.548), indicating that firms with higher indirect emissions may also exhibit stronger profitability, possibly due to

greater operational output or efficiency.

Scope 1 emissions display a strong negative correlation with leverage (r = -0.602), implying that highly polluting firms may be less inclined—or less able—to rely on debt financing, potentially due to risk aversion from lenders or internal financing preferences. Firm size is positively associated with both sustainability reporting (r = 0.354) and leverage (r = 0.327), aligning with expectations that larger firms are more engaged in ESG transparency and possess broader access to credit markets. Collectively, the residual correlations emphasize persistent interdependencies among key variables even after fixed effects are removed, reinforcing the appropriateness of the multivariate regression framework employed in this study

Multivariate Regression Results

Table 16: Model Fit Statistics for Multivariate Regression

Dependent Variable	Observations	Parameters	RMSE	R-squared	F-Statistic	p-value
MC	24	8	1.0521	0.7846	8.33	0.0002
TOBINQ	24	8	0.4652	0.8266	10.90	0.0000

Source: Researchers' Computation (2025) using Stata 17

The R-squared values indicate that the model explains approximately 78.5% of the variation in MC and 82.7% in TOBINQ, suggesting good model fit. Both models are statistically significant based on their F-statistics and associated p-values, confirming that the included independent variables jointly explain a substantial portion of the variance in firm value metrics.

Table 17a: Multivariate Regression Results - MC Model

Variable	Coef	Std. Err.	t	p-value
S1	16.4919	198.9491	0.08	0.935
S2	-263.2225	697.5681	-0.38	0.711
S3	799.4924	611.2740	1.31	0.209
SRS	0.3319	0.5904	0.56	0.582
FS	0.9220	0.2187	4.22	0.001 **
LEV	-0.0356	0.0202	-1.76	0.097
ROA	0.1281	0.0682	1.88	0.079
_cons	1.6318	4.1412	0.39	0.699

Table 17b: Multivariate Regression Results - TOBINQ

Variable	Coef	Std. Err.	t	p-value
S1	-9.2177	87.9682	-0.10	0.918
S2	710.0942	308.4396	2.30	0.035 **
S3	488.3899	270.2835	1.81	0.090
SRS	0.1763	0.2610	0.68	0.509
FS	-0.0913	0.0967	-0.94	0.359
LEV	-0.0000191	0.0090	~0	0.998
ROA	0.0231	0.0302	0.77	0.454
_cons	2.5034	1.8311	1.37	0.190

Source: Researchers' Computation (2025) using Stata 17

The multivariate regression results reveal that Scope 2 emissions (S2) have a statistically significant and positive relationship with Tobin's Q ($p = 0.035$), indicating that firms with higher indirect emissions from purchased energy tend to enjoy greater market-based valuations. This outcome suggests that investors may interpret such emissions as a signal of operational scale and energy use intensity, which are often associated with productivity and firm growth. Scope 3 emissions (S3) also exhibit a positive association with Tobin's Q ($p = 0.090$), although this relationship is not statistically significant at the conventional 5% level, hinting at a potential—but less certain—investor response to emissions arising from firms' value chains.

Firm size (FS) emerges as a strong and significant predictor of market capitalization (MC) ($p = 0.001$), reinforcing the established view that larger firms tend to have greater market value due to scale advantages and visibility. In contrast, Scope 1 emissions, sustainability reporting (SRS), and leverage (LEV) did not exhibit statistically significant effects on either MC or Tobin's Q, suggesting limited investor responsiveness to direct emissions or current sustainability disclosures within the Nigerian context.

Overall, the findings underscore that among all emission scopes, Scope 2 emissions are the most robust and consistent indicator of shareholder value. This emphasizes the importance for firms to prioritize the measurement and transparent disclosure of energy-related emissions, which appear to be more salient to market participants. The results support the broader conclusion that not all carbon disclosures carry equal weight in investor decision-making, with indirect operational emissions being more closely tied to firm valuation.

Discussion of Findings

The multivariate regression analysis provides empirical evidence to test the four hypotheses related to the effects of carbon emissions disclosures (Scope 1, 2, and 3) and sustainability financial reporting on firm value in the Nigerian context. The results are discussed below in relation to each independent variable and anchored in the recent empirical literature.

Scope 1 Emissions and Firm Value

The regression output showed that Scope 1 emissions (S1) had no statistically significant effect on either market capitalization (MC) or Tobin's Q, with p-values of 0.935 and 0.918 respectively. These results indicate that direct emissions from operational activities are not priced by investors in Nigeria's capital markets. This finding aligns with Liesen et al. (2023), who argued that in many emerging markets, Scope 1 disclosures often lack rigor and comparability, reducing their informational value. Similarly, Onoh et al. (2022) observed that in Nigeria, inconsistencies and vague disclosure formats erode investor confidence in Scope 1 data. While Okike and Nwachukwu (2024) reported a positive valuation effect in the oil and gas sector under strong governance conditions, this broader analysis finds no such evidence across industries. Hence, H_{01} is not rejected, confirming that Scope 1 emissions do not significantly impact firm value among the sampled Nigerian firms.

Scope 2 Emissions and Firm Value

The results reveal that Scope 2 emissions (S2) are positively and significantly associated with Tobin's Q ($p = 0.035$), but not with MC ($p = 0.711$). This suggests that investors value Scope 2 emissions disclosure when assessing market-based performance metrics. The positive association with Tobin's Q supports the findings of Aguguom (2024), who showed that Scope 2 disclosures—especially when linked to energy-saving initiatives—enhanced investor trust and market valuations in Nigeria's manufacturing sector. Yuan and Bao (2025) also demonstrated a strong relationship between emission intensity and firm value in energy-intensive industries across Asia. Furthermore, Fatica and Panzica (2022) noted that Scope 2 disclosures are linked to improved capital access in European markets. The current study's findings reinforce these conclusions and lead to the rejection of H_{02}, establishing that Scope 2 emissions significantly affect firm value, particularly from a market valuation perspective.

Scope 3 Emissions and Firm Value

Scope 3 emissions (S3) were found to be positively associated with both MC and Tobin's Q, though the relationships were not statistically significant at the 5% level ($p = 0.209$ and 0.090, respectively). The relatively stronger association with Tobin's Q suggests that while investors may be beginning to recognize the value of comprehensive

carbon footprint disclosures, the signal is not yet consistently priced. This mixed result is consistent with the literature. Tang et al. (2025) highlighted the role of Scope 3 disclosures in improving stock performance through enhanced risk signaling. Similarly, Emovon and Ogbonmwan (2025) found positive investor reactions to SDG-aligned Scope 3 reporting in Nigeria. However, the insignificant coefficients in this study align with Onoh et al. (2022), who noted widespread inconsistencies and omissions in Scope 3 data among Nigerian firms. Therefore, H_{03} is not rejected, although the positive direction of the relationship suggests potential investor receptiveness under improved reporting conditions.

Sustainability Financial Reporting and Firm Value

Sustainability financial reporting (SRS) did not show a statistically significant effect on either MC ($p = 0.582$) or Tobin's Q ($p = 0.509$), implying that current ESG reporting practices in Nigeria do not influence firm valuation. This finding resonates with Aguguom (2024), who observed that many Nigerian firms produce sustainability reports without third-party verification, which limits their credibility and usefulness to investors. Although Easton et al. (2025) and Emovon and Ogbonmwan (2025) identified positive effects of aligned ESG disclosures in other contexts, their findings were conditional on report quality, standardization, and alignment with global frameworks like IFRS S1 and S2. Fiechter et al. (2021) further emphasized that materiality and auditability are essential for ESG disclosures to affect valuation. In the Nigerian context, where such standards are inconsistently applied, the findings here suggest limited investor confidence. Thus, H_{04} is not rejected, indicating that sustainability financial reporting, in its current form, does not significantly drive shareholder value.

Among the tested variables, Scope 2 emissions emerged as the only statistically significant and positively associated predictor of firm value, particularly in terms of Tobin's Q. Scope 1, Scope 3, and sustainability reporting, while directionally consistent with the literature, did not yield significant effects. These results reflect broader challenges in ESG data quality and reporting maturity within emerging markets and suggest that investors selectively respond to disclosures that are quantifiable, standardized, and perceived to signal operational efficiency.

Conclusion and Recommendations

This study explored the relationship between scope-based carbon emissions disclosures (Scope 1, 2, and 3) and sustainability financial reporting on firm value, using multivariate regression analysis on panel data from listed Nigerian firms between 2012 and 2023. The results revealed that among the variables studied, only Scope 2 emissions demonstrated a statistically significant positive effect on firm value, particularly when

measured by Tobin's Q. This suggests that investors in Nigeria are more responsive to indirect emissions related to energy consumption, possibly due to their clearer linkage with operational efficiency and scale. Conversely, Scope 1 and Scope 3 emissions, as well as sustainability reporting practices, showed no significant impact—highlighting a persistent gap in the credibility, consistency, or perceived materiality of such disclosures in the Nigerian context. These findings underscore the uneven valuation of carbon information in emerging markets and support the argument that only robust, standardized, and decision-useful disclosures are likely to influence capital market outcomes.

Based on the findings, firms listed in Nigeria should prioritize improving the quality and transparency of Scope 2 emissions reporting. Such disclosures should go beyond compliance and include verifiable metrics linked to energy efficiency and performance improvements, which are more likely to be rewarded by investors. Additionally, while Scope 1 and Scope 3 emissions are currently undervalued, companies should work toward enhancing the reliability and comparability of these disclosures through adherence to international standards such as the GHG Protocol or IFRS Sustainability Disclosure Standards (S1 and S2). For sustainability financial reporting to be impactful, firms must integrate ESG metrics into core strategic reporting, ensure third-party assurance, and align disclosures with materiality principles. Regulators, on their part, should provide clearer guidance and enforce minimum standards for carbon and ESG reporting, which can help build investor confidence and foster more efficient capital markets in Nigeria.

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