Carbon Emission Disclosure and Capital Structure: The Moderating Role of Audit Committee Size

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Abstract

This study examines whether carbon emission disclosure is associated with corporate capital structure and whether audit committee size conditions that association. The analysis uses 530 firm-year observations from manufacturing companies listed on the Indonesia Stock Exchange during 2019-2023. Carbon emission disclosure is measured using an 18-item binary disclosure index, while capital structure is proxied by the debt-to-equity ratio. Baseline pooled ordinary least squares results show a positive association between carbon emission disclosure and leverage (coefficient = 1.921; p = 0.012). After correcting one miscoded audit committee observation, carbon emission disclosure remained positive in the moderated model (coefficient = 1.801; p = 0.028), and the interaction with audit committee size remained positive but significant only at the 10% level (coefficient = 4.106; p = 0.081). The disclosure coefficient also remains stable under winsorization, an alternative leverage measure, firm fixed effects, firm-clustered standard errors, and an extended control specification. The study contributes by distinguishing disclosed carbon content from the governance arrangements that support its credibility and by linking both elements to the realized financing mix in an emerging market. The findings remain associational rather than causal.

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Keywords: Audit Committee Size, Capital Structure, Carbon Emission Disclosure, Corporate Governance, Emerging Market

JEL Classification: G32; G34; M41; Q56

1. Introduction

Climate-related information has moved from the margins of sustainability reporting toward the core of corporate financing analysis. Creditors and investors increasingly evaluate transition costs, regulatory exposure, carbon-intensive assets, and the reliability of non-financial information when they assess future cash flows. Carbon emission disclosure can therefore affect financing decisions because it changes what capital providers know about environmental risk, management response, and the quality of corporate oversight.

The finance literature has begun to document this link. Carbon risk awareness is associated with debt pricing because lenders can incorporate emissions exposure into credit assessments (Jung et al., 2018). More recent Indonesian evidence shows that broader carbon disclosure can reduce the cost of debt by lowering information asymmetry (Nasih et al., 2024). Evidence from China also indicates that carbon disclosure can lower debt financing costs, especially where external institutions provide weaker environmental discipline (Hu & Liang, 2024). Carbon emissions and their disclosure also affect firm value, indicating that market participants distinguish between emissions exposure and reporting transparency (Matsumura et al., 2014). Evidence from Japan similarly shows that carbon disclosure can influence corporate value through information effects (Saka & Oshika, 2014). These findings establish that carbon information has financial consequences, but financing cost is not the same as financing structure.

Research that directly examines leverage offers a less uniform picture. Climate disclosure is negatively related to long-term borrowing in Türkiye, which suggests that disclosure may reveal transition exposure or coincide with a more conservative financing strategy (Gahramanova & Kutlu Furtuna, 2023). Carbon policy risk also reduces leverage when firms respond to expected compliance costs and financing constraints (Shu et al., 2023). Carbon trading regulation produces a similar deleveraging response in Chinese energy-intensive firms (Zhang et al., 2023). In contrast, global evidence shows that carbon assurance shapes capital structure and debt maturity by improving the credibility of reported information (Bugshan et al., 2024).

Indonesia provides a useful setting because carbon reporting has developed unevenly across listed firms. The market combines growing

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environmental scrutiny with substantial variation in disclosure breadth, governance quality, and access to external finance. Ardianto et al. (2024) report a positive association between carbon disclosure and capital structure and show that a risk management committee strengthens that relationship. Their study identifies enterprise risk governance as an important boundary condition. It does not resolve whether a committee embedded in the financial reporting architecture performs a similar role.

This distinction matters. A risk management committee focuses on identifying and coordinating enterprise risks. An audit committee focuses on reporting integrity, internal control, compliance, and the reliability of information presented to capital providers. Carbon disclosure can be extensive but still have limited financing value when the underlying measurement and review process lacks credibility. Audit committee oversight may convert environmental reporting from symbolic communication into decision-useful information by linking carbon data to formal reporting controls.

The study addresses three gaps. First, it separates the financing relevance of disclosure breadth from the governance process that supports disclosure credibility. Second, it examines realized leverage rather than only the cost of debt or cost of capital. Third, it tests an internal reporting-governance mechanism in an emerging market where disclosure practices remain heterogeneous. The study does not claim that the audit committee guarantees carbon data quality. It tests whether committee size, as a limited proxy for monitoring capacity, changes the association between disclosure and leverage.

The contribution is incremental but clear. The paper extends recent capital structure research by positioning the audit committee as a credibility-related boundary condition that differs from carbon assurance, regulation, and risk management committees. It also offers a durable analytical framework. As climate reporting becomes more standardized, the central question will not disappear. Capital providers will still distinguish between disclosed content, the credibility of that content, and the financing decisions that follow. This three-part distinction can remain relevant under both voluntary and mandatory reporting regimes.

The remainder of the paper proceeds as follows. Section 2 develops the theoretical arguments and hypotheses. Section 3 explains the sample, variables, and empirical models. Section 4 presents the results and an

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integrated discussion. Section 5 concludes with implications, limitations, and directions for further research.

2. Theoretical Foundations and Hypothesis Development

2.1. Carbon emission disclosure and capital structure

Legitimacy theory explains environmental disclosure as a response to the need for continued social acceptance. Firms communicate environmental actions when stakeholders may question whether corporate conduct remains consistent with accepted norms (Suchman, 1995). Environmental reporting can also legitimize corporate conduct by aligning disclosed actions with prevailing social expectations (Deegan, 2002). Carbon disclosure can reduce a perceived legitimacy gap by showing emissions exposure, reduction policies, targets, and governance arrangements. The theory does not imply that every disclosure is substantive. It explains why firms have incentives to communicate and why external users may scrutinize the credibility of that communication.

Information asymmetry provides the direct financing mechanism. Capital providers price uncertainty when managers possess information about environmental liabilities, transition plans, and future compliance costs that outsiders cannot observe. Voluntary non-financial disclosure can reduce this gap and lower the cost of external capital (Dhaliwal et al., 2011). Carbon information is especially relevant because emissions can create operating, regulatory, and reputational exposures that affect long-term cash flows.

Capital structure theory provides two competing channels. Under trade-off reasoning, firms compare the benefits of debt with expected distress and agency costs. Better carbon disclosure can lower perceived risk and expand debt capacity when it demonstrates that transition exposure is understood and managed. Environmental risk management can also reduce financing frictions by lowering the cost of capital (Sharfman & Fernando, 2008). Under pecking order reasoning, reduced information asymmetry can make external finance less costly and reduce the penalty attached to debt issuance (Myers, 1984). Cross-country evidence identifies firm size, profitability, tangibility, and institutional conditions as recurring determinants of leverage (Rajan & Zingales, 1995). Broader evidence similarly identifies profitability, size, tangibility, and industry conditions as reliable capital structure determinants (Frank

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& Goyal, 2009). These channels predict that credible transparency can increase the feasible use of external financing, while firm characteristics continue to shape the financing mix.

The opposite direction is also possible. Detailed carbon disclosure may reveal high transition exposure, costly abatement needs, or vulnerable assets. Capital providers may then restrict debt, while managers may prefer equity to absorb transition risk. This mechanism helps explain why policy risk and carbon regulation can reduce leverage (Shu et al., 2023). It also clarifies why the empirical effect of disclosure should not be treated as universally positive.

The present study focuses on disclosure breadth rather than carbon intensity or regulatory shocks. In a setting where many firms disclose little information, an increase in reporting breadth may primarily signal managerial attention and reduce uncertainty. Prior Indonesian evidence reports a positive relation between carbon disclosure and capital structure (Ardianto et al., 2024). The expected association is therefore positive, while the discussion recognizes that its direction may vary across institutional settings and measures.

Accordingly, the first hypothesis predicts a positive disclosure-financing association. H1. Carbon emission disclosure is positively associated with corporate capital structure.

2.2. The moderating role of the audit committee

Agency theory views the audit committee as a monitoring mechanism that protects the integrity of corporate reporting. Its conventional responsibilities include oversight of financial statements, internal control, external audit, and regulatory compliance. These responsibilities are relevant to carbon reporting because emissions information relies on data collection systems, estimation choices, organizational boundaries, and management review. Weak controls can produce inconsistent or selective disclosure even when the volume of reported information appears high.

Audit committee oversight can strengthen the financing relevance of carbon disclosure through a credibility channel. First, the committee can request evidence for material environmental claims. Second, it can encourage consistency between sustainability reports, annual reports, risk disclosures, and financial assumptions. Third, it can connect carbon

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information to internal control and assurance processes. These actions can reduce the likelihood that capital providers dismiss disclosure as symbolic.

Prior evidence supports the broader governance argument but also warns against treating size as a complete measure of effectiveness. Indonesian evidence links audit committee characteristics to carbon emission disclosure (Chariri et al., 2018). Audit committee attributes also influence integrated reporting quality (Raimo et al., 2021). Committee characteristics are associated with environmental, social, and governance performance (Pozzoli et al., 2022). Audit committee leadership can affect firm performance through sustainability disclosure (Alodat et al., 2023). Board independence and environmental committees shape greenhouse gas disclosure (Liao et al., 2015). Board gender diversity can influence corporate responses to Carbon Disclosure Project initiatives (Ben-Amar et al., 2017). Governance structures are also associated with environmental performance, although the strength of that relationship varies across settings (Walls et al., 2012). International evidence shows that committee effectiveness and meeting activity support climate disclosure commitment, while committee size alone may not be significant (Dahmen & Chouaibi, 2026). Recent emerging-market research similarly stresses that audit committee governance shapes climate disclosure after regulatory change (Saha et al., 2025).

These findings imply that committee size is best interpreted as a capacity proxy, not as direct evidence of oversight quality. A larger committee may provide more time, expertise, and monitoring resources. It may also create coordination costs or add members without improving substance. The expected moderating effect is therefore theoretically positive but empirically uncertain.

The mechanism differs from the risk management committee examined by Ardianto et al. (2024). Risk governance can improve the identification and treatment of climate exposure. Audit committee governance can improve the reliability and decision usefulness of the information communicated about that exposure. This distinction provides the basis for the second hypothesis.

Accordingly, the second hypothesis predicts that stronger monitoring capacity amplifies the disclosure-financing association. H2. Audit

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committee size strengthens the positive association between carbon emission disclosure and corporate capital structure.

2.3. Analytical contribution and boundary conditions

The conceptual contribution rests on a sequence of three elements: disclosure content, reporting credibility, and financing allocation. Existing studies often test one link at a time. Cost-of-debt research connects disclosure to pricing. Carbon assurance research connects credibility to financing outcomes. Governance research connects board structures to disclosure. This study combines the three elements in a single moderation model, while recognizing that the available proxy captures only one dimension of credibility.

The framework also clarifies the conditions under which findings may persist. Mandatory reporting can increase the minimum quantity of disclosed information, but it cannot fully eliminate variation in data quality, internal control, comparability, or board oversight. The credibility channel should therefore remain relevant after disclosure rules mature. The predicted association may still change direction when disclosure exposes severe transition risk, when firms face binding carbon prices, or when lenders already possess private environmental information.

3. Data and Methodology

3.1. Research design, sample, and data sources

The study uses a quantitative explanatory design with secondary firm-year data. The population consists of manufacturing companies listed on the Indonesia Stock Exchange during 2019-2023. Purposive sampling applies four criteria. The company had to remain listed during the observation period, publish an annual report, provide the information required to measure the study variables, and make the relevant annual or sustainability reports accessible through official sources. The screening process produced 530 firm-year observations.

The unit of analysis is the firm-year. This wording is important because the sample does not represent 530 distinct companies. It represents repeated observations of listed firms across a five-year window. The period captures variation before, during, and after the most

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disruptive phase of the COVID-19 pandemic, but the model does not separately identify pandemic effects.

Data are collected from annual reports and sustainability reports. The design is observational. The estimates should therefore be read as conditional associations rather than causal effects. Reverse causality remains possible because firms with greater debt capacity may invest more in disclosure systems, and omitted firm characteristics may affect both disclosure and leverage.

3.2. Variable measurement

Table 1 presents the operational definitions and measurement rules used in the empirical analysis. These definitions ensure that each construct is measured consistently across all firm-year observations.

Table 1. Variable definitions and measurements

Variable	Symbol	Measurement
Capital structure	DER	Total liabilities divided by total equity
Carbon emission disclosure	CED	Number of disclosed carbon emission items divided by 18 disclosure items adapted from Choi et al. (2013); index ranges from 0 to 1
Audit committee size	AC	Number of audit committee members
Sales growth	SG	(Sales_t - Sales_t-1) / Sales_t-1
Firm size	SIZE	Natural logarithm of total assets
Firm age	AGE	Number of years since establishment
Profitability	ROA	Net income divided by total assets
Tangibility	TAN	Net fixed assets divided by total assets
Liquidity	LIQ	Current assets divided by current liabilities
Non-debt tax shield	NDTS	Depreciation expense divided by total assets

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The measurement design distinguishes the breadth of environmental information from the governance structure that may support its credibility. DER captures the realized debt-equity mix, but it becomes unstable when equity is small or negative. CED records disclosure breadth rather than assurance quality or carbon performance, while AC captures committee capacity through membership count rather than independence, expertise, meeting frequency, or actual monitoring behavior. The extended controls represent earnings capacity, collateral availability, short-term financial flexibility, and depreciation-related tax benefits that commonly influence leverage decisions.

Carbon emission disclosure was measured using an 18-item binary checklist adapted from Choi et al. (2013), which operationalized the Carbon Disclosure Project framework. Prior research shows that Carbon Disclosure Project responses and corporate reports can differ in coverage, which supports a transparent report-based coding protocol (Depoers et al., 2016). The item-level content and equal-weighted scoring follow the established instrument. For analytical presentation, the 18 items were regrouped into six dimensions by separating climate-change strategies and targets from the broader risk, opportunity, governance, and reduction categories. This reclassification does not alter the underlying disclosure items or the calculation of the index. Each item received a score of 1 when the relevant information appeared in an annual report or sustainability report and 0 otherwise. The CED index equals the number of disclosed items divided by 18, producing a score from 0 to 1.

The coding unit was the firm-year report, and each disclosure decision was matched to a predefined item definition before a score was assigned. Two coders independently coded all 530 firm-year reports, generating 9,540 item-level disclosure decisions for each coding round. Observed agreement reached 93.8%, expected agreement was 56.5%, and Cohen's kappa was 0.86. This value indicates almost perfect intercoder agreement and supports the reliability of the content-analysis procedure.

Table 2 summarizes the six-dimension presentation and item allocation used for the 18-item carbon emission disclosure checklist. The allocation preserves the original item-level scoring while making the strategy and target disclosures visible as a separate analytical dimension.

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Table 2. Adapted six-dimension presentation of the carbon emission disclosure checklist

Dimension	Number of Items
Climate change risks and opportunities	2
Greenhouse gas emissions accounting	5
Energy consumption	3
Emission reduction initiatives and costs	4
Carbon emission accountability and governance	2
Climate change strategy and targets	2
Total items	18

The adapted presentation assigns the largest share of items to greenhouse gas emissions accounting and emission-reduction initiatives and costs, which together account for 9 of the 18 items. Two items concerning climate-change strategy and targets are displayed separately to clarify the forward-looking component of disclosure, although they remain part of the same 18-item instrument. The maximum observed CED value of 0.78 is consistent with disclosure of 14 items after rounding, whereas a score of 0 indicates that no checklist item was identified. Equal weighting supports transparent replication, but it does not distinguish the materiality, precision, or external assurance of individual disclosures. Environmental disclosure breadth should also be distinguished from environmental performance because the two constructs may not move together (Clarkson et al., 2008). Carbon disclosure strategy can likewise diverge from realized carbon performance (Datt et al., 2019).

3.3. Empirical models

Equation (1) tests H1 by estimating the association between carbon emission disclosure and capital structure, as measured by the debt-to-equity ratio. Equation (2) tests H2 by incorporating the main effect of audit committee size and the interaction between carbon emission disclosure and audit committee size. Sales growth, firm size, and firm age are retained in both specifications. An extended model subsequently adds profitability, asset tangibility, liquidity, and non-debt tax shield to assess coefficient stability.

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$$DER_{i,t} = \beta_0 + \beta_1 CED_{i,t} + \beta_2 SG_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 AGE_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$DER_{i,t} = \beta_0 + \beta_1 CED_{i,t} + \beta_2 AC_{i,t} + \beta_3 (CED_{i,t} \times AC_{i,t}) + \beta_4 SG_{i,t} + \beta_5 SIZE_{i,t} + \beta_6 AGE_{i,t} + \varepsilon_{i,t} \quad (2)$$

In these equations, $DER_{i,t}$ denotes the debt-to-equity ratio of firm i in year t, $CED_{i,t}$ represents the carbon emission disclosure index, and $AC_{i,t}$ denotes audit committee size. The interaction term $CED_{i,t} \times AC_{i,t}$ captures whether audit committee size changes the association between disclosure and leverage, while $SG_{i,t}$, $SIZE_{i,t}$, and $AGE_{i,t}$ represent the baseline control variables. A positive and statistically significant β_1 in Equation (1) supports H1, whereas a positive and statistically significant β_3 in Equation (2) supports H2. Results at the 10% level are interpreted as marginal rather than conclusive support.

3.4. Estimation scope and methodological safeguards

Baseline associations are estimated using pooled ordinary least squares across the 530 firm-year observations. The direct model reports the association between CED and DER, while the moderated model includes the main effects of CED and AC, their interaction, and the baseline controls. Conventional pooled OLS inference is reported for the baseline tables. A separate specification clusters standard errors by firm, providing inference that is robust to heteroskedasticity and within-firm error dependence.

The empirical results are presented through coefficient estimates, t-statistics, and p-values. Statistical significance is evaluated at the 1%, 5%, and 10% levels, with 10% evidence treated as marginal. Robustness tests include winsorization at the 1st and 99th percentiles, an alternative debt-to-assets measure, firm fixed effects, firm-clustered standard errors, an audit committee data-quality correction, and an extended control specification. The content-analysis procedure is supported by double coding and Cohen's kappa of 0.86. The interaction specification includes both lower-order terms, which preserves the correct hierarchical structure of the moderation model.

The descriptive statistics indicate extreme DER observations and negative equity, both of which can influence pooled OLS estimates. Winsorization and the alternative leverage measure assess whether the central findings depend on a small number of extreme ratios. The firm

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fixed-effects model evaluates whether the coefficient direction persists after controlling for time-invariant firm characteristics, while the extended model reduces omitted-variable concerns related to profitability, collateral, liquidity, and tax shields.

4. Empirical Analysis and Discussion

4.1. Descriptive evidence

Table 3 summarizes the distribution of the study variables for 530 firm-year observations. The statistics describe the central tendency, dispersion, and observed range of each construct before regression analysis.

Table 3. Descriptive statistics

Variable	N	Min.	Max.	Mean	Std. dev.
DER	530	-14.89	39.03	1.2801	3.30760
CED	530	0.00	0.78	0.2807	0.20215
AC	530	2.00	5.00	3.0210	0.27600
SG	530	-0.74	6.50	0.1075	0.48210
SIZE	530	16.47	35.90	29.1794	1.75144
AGE	530	0.00	117.00	21.4208	15.15572

The leverage distribution is highly dispersed. The negative minimum indicates that some observations have negative equity, while the maximum reflects an unusually high ratio caused by heavy debt use, a small equity base, or both. The standard deviation is more than twice the mean. This pattern confirms that the average alone does not represent the financial condition of all sample firms.

The mean disclosure score is 0.2807. The typical firm reports fewer than one-third of the carbon-related items in the index. A zero minimum shows that some annual or sustainability reports contain no coded carbon information. The maximum of 0.78 indicates that even the most transparent observations do not report every item. This variation provides empirical scope for testing whether differences in disclosure breadth are associated with financing choices.

Audit committee size shows limited dispersion after the verified data correction. One observation recorded as 1 was corrected to 3, producing a minimum of 2, a mean of 3.0210, and a standard deviation of 0.2760. The available verification identified no additional miscoding, so the remaining

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minimum of 2 was retained rather than adjusted mechanically. The observed distribution indicates that most sample firms cluster around three committee members and that cross-firm variation is narrow. This concentration limits the statistical power of the interaction test and helps explain why the moderating evidence remains weaker than the direct disclosure result.

Sales growth is positive on average but volatile across observations. Firm size indicates a sample dominated by large listed entities. Firm age ranges from newly established firms to companies with long operating histories. These variables capture different dimensions of financing demand and organizational maturity, although they do not fully represent profitability, asset tangibility, liquidity, or tax shields.

4.2. Direct association between disclosure and capital structure

Table 4 reports the direct regression estimates for carbon emission disclosure and the control variables. The estimates provide the basis for evaluating H1 and the independent contribution of each control variable.

Table 4. Direct regression results

Variable	Coefficient	t-statistic	p-value
CED	1.921	2.514	0.012**
SG	-0.586	-1.845	0.066*
SIZE	0.028	0.315	0.753
AGE	0.002	0.202	0.840

Note. N = 530 firm-year observations. The table reports coefficients, t-statistics, and p-values. * p < 0.10; ** p < 0.05; *** p < 0.01.

The coefficient for CED is positive and statistically significant at the 5% level. H1 is supported. Because the index ranges from zero to one, a 0.10 increase in disclosure is associated with an estimated 0.192 increase in DER, holding the reported controls constant. The magnitude is economically meaningful relative to the sample mean, but the extreme distribution of DER requires caution.

The result supports the information channel. Firms that report more carbon-related information may reduce uncertainty about environmental exposure and managerial response. Lower uncertainty can expand debt capacity or make external financing more accessible. This interpretation is consistent with evidence that carbon disclosure reduces debt financing costs (Hu & Liang, 2024). It also aligns with Indonesian evidence that

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disclosure lowers the cost of debt when it reduces information asymmetry (Nasih et al., 2024).

The positive sign is also consistent with the Indonesian capital structure findings reported by Ardianto et al. (2024). The present study differs by focusing on audit committee size rather than the presence of a risk management committee. The similarity in the direct effect suggests that the disclosure-financing link is not confined to one governance specification.

The finding does not imply that carbon exposure itself increases optimal debt. Carbon risk and carbon disclosure are distinct constructs. Carbon policy risk can reduce leverage because it raises expected compliance costs and financial constraints (Shu et al., 2023). Carbon trading regulation can also encourage deleveraging in emission-intensive sectors (Zhang et al., 2023). The positive result in this study is therefore best interpreted as the financing relevance of transparency, not as evidence that high emissions improve borrowing capacity.

The negative SG coefficient is significant only at the 10% level. One explanation is that growing firms rely on retained earnings or equity when debt capacity is constrained. The result remains weak and should not support a broad claim about financing hierarchy. SIZE and AGE are not significant. Their insignificance means that these variables add little explanatory power in the reported specification, not that scale and maturity never matter for capital structure.

4.3. Moderating role of the audit committee

Table 5 reports the complete moderated regression estimated before the one-record audit committee correction. The full coefficient set and model-fit statistics document the specified model, while the corrected focal coefficients reported subsequently are treated as the preferred estimates for evaluating H2.

Table 5. Complete moderated regression before the audit committee data correction

Variable	Coefficient	t-statistic	p-value
Constant	-1.462	-1.390	0.165
CED	1.784	2.170	0.031**
AC	0.284	0.880	0.380
CED × AC	4.194	1.726	0.085*
SG	-0.542	-1.720	0.086*

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Variable	Coefficient	t-statistic	p-value
SIZE	0.036	0.470	0.640
AGE	0.003	0.340	0.732

Note. N = 530 firm-year observations. R^2 = 0.126; adjusted R^2 = 0.116; F-statistic = 12.54; Prob > F = 0.000. The table reports conventional pooled OLS coefficients, t-statistics, and p-values. * p < 0.10; ** p < 0.05; *** p < 0.01.

The complete pre-correction model reports a positive CED coefficient of 1.784 with a p-value of 0.031, while AC has a positive but statistically insignificant main effect. The interaction coefficient is 4.194 with a p-value of 0.085. These estimates provide the complete baseline specification, but the corrected focal estimates are used for the preferred hypothesis inference because they incorporate the verified audit committee value.

Table 6 presents the audit committee data correction and the preferred focal estimates from the corrected moderated model. The comparison evaluates whether the verified adjustment changes the distribution of AC or the substantive inference for CED, AC, and their interaction.

Table 6. Audit committee data correction and preferred focal estimates

Statistic or variable	Before correction	After correction	Inference
AC minimum	1.000	2.000	Corrected distribution
AC mean	3.017	3.021	Minimal change
AC standard deviation	0.285	0.276	Minimal change
CED coefficient	1.784 (p = 0.031)	1.801 (p = 0.028)	Positive and significant
AC coefficient	0.284 (p = 0.380)	0.301 (p = 0.352)	Not significant
CED × AC coefficient	4.194 (p = 0.085)	4.106 (p = 0.081)	Marginally significant

The correction produces only small changes in the mean, dispersion, and focal regression coefficients. In the corrected model, CED remains positive and significant at the 5% level, AC remains insignificant, and the interaction remains positive with marginal significance at the 10% level. The corrected interaction coefficient of 4.106 with a p-value of 0.081 is therefore used to evaluate H2, which receives marginal rather than conclusive support. The principal conclusions do not depend on the miscoded observation.

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The positive direction is consistent with the credibility mechanism. A committee with greater capacity may ask more questions about data sources, reporting boundaries, measurement assumptions, and consistency across corporate reports. When these processes improve, capital providers may place more weight on carbon disclosure when they assess risk and financing capacity.

The weak significance is theoretically informative. Audit committee size is a coarse governance measure, and the descriptive statistics show very little variation. International evidence indicates that committee effectiveness and meeting activity matter for climate disclosure commitment, while size alone may be insignificant (Dahmen & Chouaibi, 2026). The current result therefore supports a capacity interpretation but does not establish that larger committees are necessarily more effective.

The moderation result also adds a governance distinction to the literature. Carbon assurance affects capital structure because an external party validates reported information (Bugshan et al., 2024). A risk management committee affects the disclosure-financing relationship because it strengthens enterprise risk governance (Ardianto et al., 2024). The audit committee represents an internal reporting-control channel. These mechanisms can complement one another, but they should not be treated as interchangeable.

Recent research in emerging markets emphasizes that climate disclosure depends on the institutional and governance environment surrounding the reporting process (Saha et al., 2025). The marginal result in this study is consistent with that broader view. Governance may determine whether disclosure is decision-useful, but a headcount measure cannot fully capture that function.

4.4. Integrated discussion, novelty, and lasting contribution

The integrated findings support a two-stage explanation. Carbon disclosure is first associated with leverage through an information channel. Audit committee capacity then appears to strengthen the association through a credibility channel. This explanation adds precision to legitimacy-based arguments. Disclosure can help maintain legitimacy, but financing consequences depend on whether capital providers treat the information as reliable and relevant.

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The study advances the literature in three specific ways. It tests the financing mix rather than only the price of capital. It identifies an audit committee boundary condition that differs from regulation, assurance, and risk management governance. It also provides evidence from an emerging market where disclosure remains uneven and committee structures are relatively concentrated. These features make the setting analytically useful even though they limit broad generalization.

The novelty should not be overstated. A closely related Indonesian study already documents the moderating role of a risk management committee (Ardianto et al., 2024). The present contribution lies in the governance mechanism, not in claiming the first disclosure-capital structure model. By stating this boundary clearly, the paper offers a more credible and defensible contribution.

The contribution can remain relevant over time because mandatory climate reporting will not eliminate the need for credible internal governance. Standardization may reduce variation in whether firms disclose. It will not fully remove variation in estimation quality, control systems, assurance, board attention, or the integration of climate information into financing decisions. The content-credibility-allocation framework therefore has the potential to survive changes in specific reporting rules.

The results also help reconcile mixed empirical findings. Disclosure can increase leverage when transparency reduces uncertainty and expands debt capacity. It can reduce leverage when disclosure reveals material transition exposure or accompanies costly regulation. The direction depends on what the disclosure communicates, how credible it is, and how lenders interpret the institutional context. This conditional explanation is more durable than a universal claim that carbon disclosure always raises or lowers debt.

4.5. Robustness and extended specifications

Table 7 compares the focal coefficients across the baseline and four robustness specifications. The CED column reports the disclosure coefficient from the corresponding direct specification, while the interaction column reports the CED × AC coefficient from the corresponding moderated specification. The tests evaluate sensitivity to

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outliers, leverage measurement, time-invariant firm characteristics, and within-firm error dependence.

Table 7. Robustness tests

Model	CED	CED × AC	Adj. R^2	Result
Baseline OLS	1.921**	4.194*	0.116	Supported
Winsorized 1%-99%	1.846**	3.981*	0.121	Consistent
Alternative leverage (debt/assets)	0.294**	0.612*	0.134	Consistent
Firm fixed effects	1.633*	3.541	0.109	Direction unchanged
Clustered standard errors	1.921**	4.194*	0.116	Robust

Note. * p < 0.10; ** p < 0.05; *** p < 0.01. The CED column reports the focal coefficient from each direct specification, whereas the CED × AC column reports the interaction coefficient from the corresponding moderated specification. The firm-clustered specification changes statistical inference rather than the pooled OLS point estimates.

The CED coefficient remains positive and statistically significant across all reported specifications. The interaction remains positive and marginally significant under winsorization, the alternative leverage measure, and firm-clustered inference, but it loses statistical significance in the firm fixed-effects model. The coefficient direction is therefore stable, while the strength of H2 is specification-sensitive. This pattern confirms that the direct disclosure association is more robust than the moderating effect.

Table 8 reports the extended specification that adds profitability, asset tangibility, liquidity, and non-debt tax shield. The additional controls test whether the focal coefficients persist after accounting for major firm-level determinants of capital structure.

Table 8. Extended model with additional capital structure controls

Variable	Coefficient	p-value
CED	1.642	0.041**
AC	0.311	0.331
CED × AC	3.928	0.074*
SG	-0.498	0.091*
SIZE	0.041	0.603
AGE	0.004	0.701
Profitability (ROA)	-0.912	0.009***
Tangibility	0.658	0.018**
Liquidity	-0.287	0.036**
Non-debt tax shield	-0.174	0.112

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Note. N = 530 firm-year observations. R^2 = 0.184; adjusted R^2 = 0.169; F-statistic = 13.87; Prob > F = 0.000. * p < 0.10; ** p < 0.05; *** p < 0.01.

The extended model retains a positive and significant CED coefficient and a positive interaction that remains marginally significant. Profitability and liquidity are negatively associated with leverage, while tangibility is positively associated with leverage, which is consistent with the financing roles of internal funds, short-term financial flexibility, and collateral. The improved adjusted R^2 indicates that the additional controls increase explanatory power without reversing the study's principal conclusions.

4.6. Methodological limitations

The robustness tests strengthen the stability of the reported associations, but they do not eliminate endogeneity or establish causality. Reverse causality remains possible because firms with greater financing capacity may invest more heavily in carbon reporting systems. Dynamic panel estimators, external instruments, or quasi-experimental regulatory designs would provide stronger identification.

Construct validity remains limited by the use of audit committee headcount and a binary disclosure-breadth index. Future research should examine committee independence, accounting and sustainability expertise, meeting activity, external assurance, quantified emissions, targets, transition plans, and realized carbon performance. Firm-clustered inference addresses heteroskedasticity and within-firm error dependence in the reported sensitivity analysis. Formal variance inflation factors are not available in the reported summary output, so multicollinearity is not characterized numerically. The inclusion of all lower-order terms and the stability of the focal coefficients across alternative specifications reduce, but do not eliminate, concerns about model instability.

5. Conclusion

This study examines the association between carbon emission disclosure and capital structure in Indonesian manufacturing firms and evaluates audit committee size as a moderating variable. The analysis covers 530 firm-year observations from 2019-2023. Carbon disclosure is positively associated with DER in both the direct and corrected moderated models, while the interaction with audit committee size is

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positive but significant only at the 10% level. The central coefficient remains stable under winsorization, an alternative leverage measure, firm fixed effects, firm-clustered standard errors, the audit committee data correction, and an extended control specification.

The findings suggest that carbon disclosure can function as financing information rather than only as a sustainability communication tool. The positive direct association is consistent with reduced information asymmetry and greater access to external financing. The marginal interaction indicates that internal reporting governance may strengthen this relationship, but audit committee size alone is not a sufficiently rich measure of effectiveness.

The scientific contribution lies in separating disclosure content from governance-supported credibility and linking both to the realized financing mix. This distinction extends recent work on cost of debt, carbon assurance, carbon policy risk, and risk management committees. It also offers a framework that can remain useful as climate reporting becomes more standardized.

The practical implication is direct. Managers should improve both the breadth and the control environment of carbon reporting. Audit committees should review data ownership, estimation methods, reporting boundaries, and consistency with financial risk disclosures. Creditors should evaluate governance and assurance together with the volume of environmental information.

The limitations remain material despite the robustness tests and the strong intercoder agreement indicated by Cohen’s kappa of 0.86. The study uses observational data, a disclosure-breadth index, audit committee size, and leverage measures that can be affected by negative or unusually small equity. The models do not establish causality, and the moderating effect is less stable than the direct disclosure coefficient. Future research should use stronger identification strategies, richer governance measures, and complete multicollinearity and heteroskedasticity diagnostics.

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Declaration of AI-Assisted Technologies

DeepL translation technology was used to assist in translating and refining the language of this manuscript during the preparation process.

All authors reviewed and approved the final version of the manuscript and take full responsibility for the content of the article.

References

Alodat, A. Y., Al Amosh, H., Khatib, S. F. A., & Mansour, M. (2023). Audit committee chair effectiveness and firm performance: The mediating role of sustainability disclosure. *Cogent Business & Management*, *10*(1), 2181156. https://doi.org/10.1080/23311975.2023.2181156

Ardianto, A., Anridho, N., Cahyono, S., Noman Alam, A. H. M., & Harymawan, I. (2024). The role of risk management committee on the relationship between corporate carbon emission disclosure and capital structure. *Corporate Social Responsibility and Environmental Management*, *31*(3), 2127–2158. https://doi.org/10.1002/csr.2671

Ben-Amar, W., Chang, M., & McIlkenny, P. (2017). Board gender diversity and corporate response to sustainability initiatives: Evidence from the Carbon Disclosure Project. *Journal of Business Ethics*, *142*(2), 369–383. https://doi.org/10.1007/s10551-015-2759-1

Bugshan, A., Alnori, F., Bakry, W., & Datt, R. (2024). Carbon assurance, corporate capital structure, and debt maturity: Global evidence. *Economics Letters*, *245*, 112067. https://doi.org/10.1016/j.econlet.2024.112067

Chariri, A., Januarti, I., & Yuyetta, E. N. A. (2018). Audit committee characteristics and carbon emission disclosure. *E3S Web of Conferences*, *73*, 02001. https://doi.org/10.1051/e3sconf/20187302001

Choi, B. B., Lee, D., & Psaros, J. (2013). An analysis of Australian company carbon emission disclosures. *Pacific Accounting Review*, *25*(1), 58–79. https://doi.org/10.1108/01140581311318968

Clarkson, P. M., Li, Y., Richardson, G. D., & Vasvari, F. P. (2008). Revisiting the relation between environmental performance and environmental disclosure: An empirical analysis. *Accounting, Organizations and Society*, *33*(4–5), 303–327. https://doi.org/10.1016/j.aos.2007.05.003

Dahmen, I., & Chouaibi, J. (2026). The effect of audit committee effectiveness on climate change disclosure commitment: International evidence. *EuroMed Journal of Business*, *21*(2), 401–431. https://doi.org/10.1108/EMJB-12-2023-0343

Uncorrected Proof

Datt, R. R., Luo, L., & Tang, Q. (2019). Corporate voluntary carbon disclosure strategy and carbon performance in the USA. *Accounting Research Journal*, *32*(3), 417–435. https://doi.org/10.1108/ARJ-02-2017-0031

Deegan, C. (2002). Introduction: The legitimising effect of social and environmental disclosures. *Accounting, Auditing & Accountability Journal*, *15*(3), 282–311. https://doi.org/10.1108/09513570210435852

Depoers, F., Jeanjean, T., & Jérôme, T. (2016). Voluntary disclosure of greenhouse gas emissions: Contrasting the Carbon Disclosure Project and corporate reports. *Journal of Business Ethics*, *134*(3), 445–461. https://doi.org/10.1007/s10551-014-2432-0

Dhaliwal, D. S., Li, O. Z., Tsang, A., & Yang, Y. G. (2011). Voluntary nonfinancial disclosure and the cost of equity capital: The initiation of corporate social responsibility reporting. *The Accounting Review*, *86*(1), 59–100. https://doi.org/10.2308/accr.00000005

Frank, M. Z., & Goyal, V. K. (2009). Capital structure decisions: Which factors are reliably important? *Financial Management*, *38*(1), 1–37. https://doi.org/10.1111/j.1755-053X.2009.01026.x

Gahramanova, G., & Kutlu Furtuna, O. (2023). Corporate climate change disclosures and capital structure strategies: Evidence from Türkiye. *Journal of Capital Markets Studies*, *7*(2), 140–155. https://doi.org/10.1108/JCMS-10-2023-0039

Hu, Y., & Liang, Y. (2024). Impact of carbon disclosure on debt financing costs. *Chinese Journal of Population, Resources and Environment*, *22*(1), 98–108. https://doi.org/10.1016/j.cjpre.2024.03.009

Jung, J., Herbohn, K., & Clarkson, P. (2018). Carbon risk, carbon risk awareness and the cost of debt financing. *Journal of Business Ethics*, *150*(4), 1151–1171. https://doi.org/10.1007/s10551-016-3207-6

Liao, L., Luo, L., & Tang, Q. (2015). Gender diversity, board independence, environmental committee and greenhouse gas disclosure. *The British Accounting Review*, *47*(4), 409–424. https://doi.org/10.1016/j.bar.2014.01.002

Matsumura, E. M., Prakash, R., & Vera-Muñoz, S. C. (2014). Firm-value effects of carbon emissions and carbon disclosures. *The Accounting Review*, *89*(2), 695–724. https://doi.org/10.2308/accr-50629

Myers, S. C. (1984). The capital structure puzzle. *The Journal of Finance*, *39*(3), 575–592. https://doi.org/10.1111/j.1540-6261.1984.tb03646.x

Uncorrected Proof

Nasih, M., Puspitasari, A., Harymawan, I., Gautama Putra, F. K., & Djajadikerta, H. G. (2024). The relationship of carbon emission disclosure on the cost of debt. *SAGE Open*, *14*(4), 1–16. https://doi.org/10.1177/21582440241292134

Pozzoli, M., Pagani, A., & Paolone, F. (2022). The impact of audit committee characteristics on ESG performance in the European Union member states: Empirical evidence before and during the COVID-19 pandemic. *Journal of Cleaner Production*, *371*, 133411. https://doi.org/10.1016/j.jclepro.2022.133411

Raimo, N., Vitolla, F., Marrone, A., & Rubino, M. (2021). Do audit committee attributes influence integrated reporting quality? An agency theory viewpoint. *Business Strategy and the Environment*, *30*(1), 522–534. https://doi.org/10.1002/bse.2635

Rajan, R. G., & Zingales, L. (1995). What do we know about capital structure? Some evidence from international data. *The Journal of Finance*, *50*(5), 1421–1460. https://doi.org/10.1111/j.1540-6261.1995.tb05184.x

Saha, A. K., Jahan, N., & Khan, I. (2025). Audit committee governance and climate change disclosures: Regulatory reform and COVID-19 aftermath in an emerging economy. *Asian Review of Accounting*. Advance online publication. https://doi.org/10.1108/ARA-06-2025-0202

Saka, C., & Oshika, T. (2014). Disclosure effects, carbon emissions and corporate value. *Sustainability Accounting, Management and Policy Journal*, *5*(1), 22–45. https://doi.org/10.1108/SAMPJ-09-2012-0030

Sharfman, M. P., & Fernando, C. S. (2008). Environmental risk management and the cost of capital. *Strategic Management Journal*, *29*(6), 569–592. https://doi.org/10.1002/smj.678

Shu, H., Tan, W., & Wei, P. (2023). Carbon policy risk and corporate capital structure decision. *International Review of Financial Analysis*, *86*, 102523. https://doi.org/10.1016/j.irfa.2023.102523

Suchman, M. C. (1995). Managing legitimacy: Strategic and institutional approaches. *Academy of Management Review*, *20*(3), 571–610. https://doi.org/10.2307/258788

Walls, J. L., Berrone, P., & Phan, P. H. (2012). Corporate governance and environmental performance: Is there really a link? *Strategic Management Journal*, *33*(8), 885–913. https://doi.org/10.1002/smj.1952

Zhang, Z., Liao, J., Li, H., & Pan, J. (2023). Impact of carbon trading policy on corporate capital structure: Empirical evidence from China. *Frontiers in Environmental Science*, *11*, 1141212. https://doi.org/10.3389/fenvs.2023.1141212

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Uncorrected Proof