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Corporate governance structures and carbon disclosure quality: a dynamic panel analysis with environmental performance moderation

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Abstract

Climate change has elevated the importance of transparent carbon disclosure as firms face increasing scrutiny from regulators, investors, and global stakeholders. In emerging economies, however, disclosure practices remain uneven due to voluntary reporting regimes and varying governance capacities. This study investigates how corporate governance structures, specifically board size and sustainability committee capacity influence carbon disclosure quality, and examines whether this relationship is strengthened by firms' environmental performance. Using a balanced panel of 185 non-financial manufacturing firms listed on the Indonesia Stock Exchange from 2018 to 2024, the analysis employs two-step System Generalized Method of Moments (System GMM) to address endogeneity, unobserved heterogeneity, and the dynamic nature of disclosure behavior. Carbon disclosure quality is measured through a weighted index derived from GRI 305 and the Greenhouse Gas Protocol, while environmental performance is captured using Indonesia's PROPER rating system. The results show that carbon disclosure is strongly persistent across years, and both board size and sustainability committee capacity significantly enhance disclosure depth. Environmental performance not only improves reporting quality directly but also strengthens the effect of sustainability committee capacity, indicating a complementary relationship between internal governance oversight and verified environmental achievement. These findings contribute to climate-governance literature by integrating governance structures, external performance validation, and the dynamic progression of carbon reporting. They also offer practical insights for firms and regulators seeking to improve climate-related transparency.

Keywords: Carbon Disclosure, Corporate Governance, Sustainability Committee, Environmental Performance, System GMM, Indonesia.

INTRODUCTION

Climate change has become a central concern for policymakers, investors, and society, leading to a growing expectation that firms disclose their greenhouse gas (GHG) emissions transparently. Carbon disclosure has evolved into a critical element of corporate accountability, providing evidence of firms' environmental impacts and their efforts to manage climate-related risks. Despite this global momentum, reporting practices in emerging markets such as Indonesia remain inconsistent. The voluntary nature of sustainability reporting and differences in corporate governance structures often result in disclosure that varies widely in depth, accuracy, and transparency.

Corporate governance plays a crucial role in shaping how firms manage and communicate climate-related information. Oversight bodies such as boards of commissioners and sustainability committees influence managerial decision-making, strengthen monitoring of environmental risks, and support the adoption of more structured reporting systems. Larger boards typically offer broader expertise and improved supervisory capacity, while well-resourced sustainability committees can

enhance data collection, emissions monitoring, and climate-related policy implementation. These governance attributes are therefore expected to contribute to higher-quality carbon reporting.

Carbon disclosure, however, does not evolve instantly. Firms typically develop climate-reporting practices gradually as they refine internal systems, build technical expertise, and become familiar with recognized reporting frameworks such as GRI 305 and the Greenhouse Gas Protocol. This cumulative process creates a path-dependent pattern in which past disclosure influences current reporting performance. Traditional static models fail to capture this dynamic behavior, highlighting the importance of methodological approaches capable of accounting for disclosure persistence.

Environmental performance also shapes reporting behavior. In Indonesia, the PROPER program provides an externally verified assessment of firms' environmental management and compliance. Firms with higher PROPER ratings often have stronger incentives to disclose carbon information to reinforce legitimacy, differentiate themselves from weaker performers, and signal environmental responsibility to stakeholders. However, few studies have examined whether environmental performance enhances the effectiveness of internal governance mechanisms, particularly sustainability committees in improving disclosure quality.

These considerations reveal several gaps in existing research: many studies do not account for the dynamic nature of carbon disclosure; sustainability committees are often measured only by their existence rather than their capacity; and the moderating role of externally validated environmental performance remains underexplored, particularly in emerging-market contexts.

To address these gaps, this study investigates whether carbon disclosure quality exhibits persistence over time; how board size and sustainability committee capacity influence disclosure; how environmental performance affects reporting quality; and whether environmental performance strengthens the influence of sustainability committee capacity. Using a weighted disclosure index aligned with global standards and applying a System GMM estimator, the study offers a more comprehensive understanding of carbon-governance dynamics within Indonesia's manufacturing sector.

Contributions of the study:

Theoretical Contributions

- The study integrates **Governance Theory**, **Legitimacy Theory**, and **Signaling Theory** to explain carbon disclosure in an emerging market context.
- It extends prior work by examining **sustainability committee capacity** rather than just the existence of a committee, offering a more detailed understanding of internal governance mechanisms.
- The inclusion of **environmental performance as a moderator** introduces a new theoretical dimension, showing how external performance credentials strengthen the effect of internal governance structures.
- The dynamic specification demonstrates that carbon disclosure is **path-dependent**, adding theoretical insight into the cumulative nature of sustainability reporting.

Methodological Contributions

- This study applies a **two-step System GMM** estimator, which addresses endogeneity and captures the dynamic behavior of disclosure, an approach rarely used in Indonesian sustainability reporting studies.
- The **weighted carbon disclosure index** combines GRI 305 and GHG Protocol standards, contributing a more rigorous measure of disclosure quality.
- The **composite measurement of sustainability committee capacity** (size, expertise, meeting frequency) provides a more valid operationalization that future research can adopt.

Practical / Managerial Contributions

- The findings highlight the importance of strengthening **board oversight** and **sustainability committee capacity** to improve carbon reporting quality.
- The results provide evidence for firms to invest in environmental management systems because **better environmental performance enhances the effectiveness** of governance mechanisms.
- Policymakers can use these findings to design guidelines that encourage firms to improve environmental performance and reporting structures simultaneously.

Policy Contributions

- The study offers insights for Indonesian regulators as the country moves toward stricter ESG reporting requirements.
- It supports potential alignment with **international standards** (GRI 305, GHG Protocol) by showing that firms with stronger governance structures are better prepared for comprehensive carbon reporting.

THEORETICAL FRAMEWORK

Understanding how corporate governance structures shape carbon disclosure practices requires a theoretical foundation that explains both internal decision-making processes and external pressures influencing firms' reporting behavior. Although no single theory fully captures the complexities of climate-related disclosure, several established frameworks offer insights into why governance mechanisms, environmental outcomes, and firm-level incentives jointly influence carbon transparency. The theories used in this study, Governance Theory, Legitimacy Theory, and Signaling Theory do not always speak directly to carbon disclosure, but they provide coherent and complementary explanations for the indirect pathways through which organizational structures and performance shape environmental reporting.

Governance Theory

Governance Theory explains how oversight structures influence managerial decisions and accountability mechanisms within firms. While the theory does not specifically address carbon disclosure, it clarifies the broader processes through which boards and committees shape strategic directions. Internal governance bodies such as boards of commissioners and sustainability committees encourage managerial compliance with environmental requirements, enhance supervisory capacity, and ensure that sustainability issues are integrated into corporate decision-making. Larger boards provide greater expertise and more diverse perspectives, which indirectly improves the firm's ability to monitor climate-related risks. Likewise, sustainability committees offer specialized oversight, coordinating emissions-related data collection and supporting transparent reporting. Thus, Governance Theory indirectly supports the expectation that stronger internal governance structures enhance carbon disclosure quality through improved oversight and accountability.

Legitimacy Theory

Legitimacy Theory emphasizes the importance of meeting societal expectations to maintain organizational legitimacy. Although the theory does not directly reference carbon emissions, it explains why firms disclose environmental information voluntarily. Stakeholders increasingly perceive environmental transparency as an indicator of responsible corporate behavior, especially in industries with significant environmental footprints. Carbon disclosure becomes a mechanism through which firms demonstrate conformity with social norms and regulatory expectations. In Indonesia, pressure from regulators, civil society, and investors has increased demand for reliable sustainability information. Legitimacy Theory therefore offers an indirect rationale for why firms with better governance structures and environmental performance provide more detailed carbon disclosures.

Signaling Theory

Signaling Theory explains how firms communicate their strengths or intentions to external parties through observable actions such as disclosure. This theory does not explicitly discuss carbon reporting, but is widely used in sustainability research to explain why firms with superior environmental performance voluntarily release more detailed information. High PROPER ratings, for example, function as positive signals of environmental capability. By complementing these ratings with comprehensive carbon disclosures, firms differentiate themselves from weaker performers and strengthen stakeholder confidence. Signaling Theory therefore indirectly justifies the moderating effect of environmental performance on the relationship between governance capacity and carbon disclosure quality.

Integrated Perspective

Together, these theories provide a multidimensional framework for understanding carbon disclosure decisions. Governance Theory describes internal structures that shape reporting processes; Legitimacy Theory captures external pressures influencing disclosure; and Signaling Theory explains voluntary transparency driven by competitive and reputational incentives. Combined, they justify the inclusion of governance variables, environmental performance, and their interaction effects in the analysis, offering a holistic explanation of how carbon disclosure quality evolves.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Carbon Disclosure Quality

Carbon disclosure has become an essential tool for communicating firms' climate-related risks, emissions management, and commitment to sustainability. For stakeholders, high-quality carbon disclosure provides clarity regarding a firm's strategic response to climate challenges and its environmental performance. In emerging economies such as Indonesia, where sustainability reporting largely remains voluntary, the level of detail, methodological rigor, and completeness of carbon-related information varies widely across firms. Prior studies indicate that carbon disclosure quality is influenced by the firm's internal readiness, including its reporting systems, governance structures, and awareness of international frameworks such as GRI 305 and the Greenhouse Gas Protocol. At the same time, external pressures from regulators, investors, and the public push firms to increase the depth and reliability of their disclosures. These insights suggest that carbon disclosure quality depends on both organizational characteristics and environmental performance, forming the basis for examining how governance structures and performance indicators shape reporting practices.

Board Size and Carbon Disclosure Quality

Board size is a widely studied component of corporate governance and is generally associated with monitoring capacity, oversight effectiveness, and access to diverse expertise. Larger boards are often viewed as better equipped to address complex strategic issues due to the broader range of knowledge and professional backgrounds they encompass. This diversity can strengthen internal discussions surrounding environmental risks and improve the level of scrutiny applied to sustainability-related decisions. Prior governance literature suggests that larger boards are more likely to engage in environmental oversight and encourage transparent disclosure practices, including sustainability and climate reporting. Although evidence specifically linking board size to carbon disclosure is still developing, theoretical reasoning and findings from related studies imply that board size contributes to better reporting quality by enhancing accountability and encouraging transparency.

Hypothesis 1: *Board size has a positive effect on carbon disclosure quality*.

Sustainability Committee Capacity and Carbon Disclosure Quality

Sustainability committees serve as specialized governance structures established to oversee environmental, social, and sustainability-related issues. Their effectiveness depends not only on their existence but also on their capacity defined by the number of members, expertise, frequency of

meetings, and resource availability. Prior research shows that sustainability committees facilitate coordination across departments, monitor environmental performance, and guide the preparation of sustainability reports. A committee with adequate capacity is better able to manage technical environmental data, interpret regulatory expectations, and ensure that carbon disclosure aligns with recognized reporting frameworks. While earlier studies often focused on the mere presence of such committees, recent research emphasizes evaluating their strength. A committee with greater capacity is expected to contribute positively to carbon disclosure by improving internal information systems, enhancing data accuracy, and supporting comprehensive reporting.

Hypothesis 2: *Sustainability committee capacity has a positive effect on carbon disclosure quality.*

Environmental Performance and Carbon Disclosure Quality

Environmental performance represents the firm's ability to achieve compliance, demonstrate effective environmental management, and implement pollution-control practices. In Indonesia, environmental performance is assessed through the PROPER rating system, which provides external validation of environmental compliance and management quality. Firms with strong performance have incentives to disclose detailed environmental information to reinforce positive perceptions and differentiate themselves from weaker performers. Existing literature indicates that environmentally responsible firms are more likely to be transparent about their emissions and environmental practices because disclosure reflects well on their reputation. When a firm performs well environmentally, carbon disclosure becomes a strategic tool to demonstrate credibility and maintain stakeholder support. Consequently, environmental performance is expected to influence carbon disclosure positively.

Hypothesis 3: *Environmental performance has a positive effect on carbon disclosure quality.*

Environmental Performance as a Moderator

Environmental performance may not only affect disclosure directly but also shape the strength of governance mechanisms. Firms with better environmental performance tend to have more advanced environmental management systems, better monitoring tools, and stronger internal controls. When such firms also have a capable sustainability committee, the combination can significantly enhance the quality of carbon disclosure. A strong committee provides oversight and coordination, while good environmental performance offers substantive data and credible environmental outcomes. Together, they create conditions for more detailed, consistent, and reliable reporting.

From a signaling perspective, firms with superior environmental performance use disclosure as a way to communicate their strengths to external parties. The incentive to disclose becomes stronger when internal governance structures such as sustainability committees are able to prepare and present high-quality reports. Therefore, environmental performance is expected to strengthen the positive influence of sustainability committee capacity on carbon disclosure quality.

Hypothesis 4: *Environmental performance positively moderates the relationship between sustainability committee capacity and carbon disclosure quality.*

RESEARCH METHOD

Research Design

This study employs a quantitative explanatory research design to examine how corporate governance structures influence carbon disclosure quality and how environmental performance moderates these relationships. The model is developed based on prior sustainability governance research and tested using panel data from Indonesian manufacturing firms. Since carbon disclosure behavior tends to evolve over time and may be influenced by prior reporting practices, a dynamic specification is adopted to capture disclosure persistence. To address concerns related to endogeneity, unobserved heterogeneity, and reverse causality, the study uses the two-step System Generalized Method of

Moments (System GMM), which is suited for panels with a relatively large number of firms and short time periods.

Population and Sample

The population consists of all non-financial manufacturing firms listed on the Indonesia Stock Exchange (IDX). Manufacturing firms are selected because they operate in environmentally sensitive industries where emissions management and disclosure are highly relevant. The sampling period covers fiscal years **2018–2024**, aligned with the availability of sustainability reports, annual reports, and PROPER ratings for environmental performance. A purposive sampling approach is used, requiring firms to meet the following criteria:

1 Availability of annual reports or sustainability reports for each year of the sampling period. Sufficient information to construct the carbon disclosure quality index.
2 Availability of governance variables, including board and sustainability committee information.
3 Availability of PROPER ratings for environmental performance.

After applying these criteria and cleaning incomplete observations, the final sample consists of **185 firm-year observations**. This dataset provides sufficient variation across firms and over time to support the dynamic and moderating effects examined.

Operational Definitions and Measurement of Variables

Carbon Disclosure Quality (CDQ)

Carbon disclosure quality is measured using a weighted index based on the Global Reporting Initiative (GRI) Standards, specifically GRI 305 on emissions and elements from the Greenhouse Gas (GHG) Protocol. The index captures emissions data, reporting boundaries, reduction strategies, targets, methodologies, and verification practices. Each disclosure item is scored as 1 if disclosed and 0 if not, with higher weights assigned to items considered more essential (e.g., Scope 1 and Scope 2 emissions, verification). The total score is divided by the maximum possible score to construct a standardized index. This approach captures both the breadth and depth of carbon-related information.

Board Size (BSIZE)

Board size refers to the total number of directors or commissioners serving on the board. The variable is measured as a simple count extracted from annual reports. Larger boards are expected to provide broader oversight and contribute positively to disclosure practices.

Sustainability Committee Capacity (SCC)

Sustainability committee capacity reflects the strength of the committee responsible for environmental and sustainability-related issues. The variable is constructed using several indicators:

- Number of committee members,
- Expertise or background in environmental or sustainability fields,
- Frequency of committee meetings,
- Committee role descriptions disclosed in reports.

To maintain consistency, these indicators are coded following a structured set of criteria, and the capacity score is computed as a composite index. A higher score represents a more capable sustainability committee.

Environmental Performance (EP)

Environmental performance is measured using the Indonesian **PROPER** rating system issued by the Ministry of Environment and Forestry. The ratings Gold, Green, Blue, Red, and Black are converted into numerical scores based on their hierarchy. Higher scores represent better environmental performance and reflect successful environmental management, compliance, and continuous improvement.

Control Variables

Control variables are included to address firm-specific characteristics known to influence disclosure quality:

- **Firm Size (FSIZE):** measured as the natural logarithm of total assets.
- **Leverage (LEV):** measured as total liabilities divided by total assets.
- **Profitability (ROA):** measured as net income divided by total assets.
- **Firm Age (AGE):** measured as the number of years since the firm's establishment.

These variables help isolate the effects of governance and environmental performance.

Table 1. Variables and Measurement

Variable	Symbol	Measurement	Scale	Data Source	Supporting Literature
Carbon Disclosure Quality	CED	Weighted index of 35 GRI 305 and GHG Protocol items; quantitative items = 2, qualitative items = 1; score = Σ(weighted disclosed items) / Σ(total weights)	Continuous (0–1)	Sustainability Reports; Annual Reports	Choi et al. (2013); Liesen et al. (2015)
Lagged Carbon Disclosure	CED(t–1)	One-year lag of CED to capture dynamic persistence	Continuous	Derived from CED	Arellano & Bond (1991); Blundell & Bond (1998)
Board Size	BSIZE	Total number of commissioners	Continuous	Annual Reports; IDX Database	Jizi et al. (2014); Ben-Amar & McIlkenny (2015)
Sustainability Committee Size	SCOM	Number of members in the sustainability/CSR/ESG committee	Continuous	Annual Reports; Corporate Governance Statements	Michelon & Parbonetti (2012); García-Sánchez & Martínez-Ferrero (2019)
Environmental Performance	PROPER	PROPER rating converted to numeric values: Gold=5, Green=4, Blue=3, Red=2, Black=1	Ordinal/Continuous	Ministry of Environment (KLHK) PROPER Database	Clarkson et al. (2008); Sari & Sutaryo (2023)
Interaction Term	SCOM × PROPER	Multiplicative interaction between SCOM and PROPER	Constructed Variable	Derived	Signaling Theory; Governance Literature

Variable	Symbol	Measurement	Scale	Data Source	Supporting Literature
Firm Size	FSIZE	Natural logarithm of total assets	Continuous	Financial Statements; IDX	Roberts (1992); Clarkson et al. (2008)
Profitability	ROA	Net income ÷ total assets	Continuous	Financial Statements	Haniffa & Cooke (2005)
Leverage	LEV	Total debt ÷ total equity	Continuous	Financial Statements	Qian & Schaltegger (2017)

Moderation Model Specification

Given that carbon disclosure may depend on previous reporting practices, the study adopts a dynamic panel model of the form:

$$\mathbf{CDQ\_it = \alpha\ CDQ\_i(t-1) + \beta 1\ BSIZE\_it + \beta 2\ SCC\_it + \beta 3\ EP\_it + \beta 4\ (SCC\_it \times EP\_it) + \gamma\ Controls\_it + \mu\_i + \varepsilon\_it}$$

Description of Variables:

- **CDQ_it** = Carbon disclosure quality for firm *i* at year *t*
- **CDQ_i(t−1)** = Lagged carbon disclosure (captures persistence)
- **BSIZE_it** = Board size
- **SCC_it** = Sustainability committee capacity
- **EP_it** = Environmental performance
- **SCC_it × EP_it** = Interaction term (moderating effect)
- **Controls_it** = Set of control variables
- **μ_i** = Firm-specific effect
- **ε_it** = Error term

Why System GMM?

System GMM (Arellano-Bover/Blundell-Bond) is used because it:

- Handles dynamic relationships through lagged dependent variables,
- Addresses endogeneity, especially in governance variables,
- Controls for firm-specific unobservables,
- Uses internal instruments to improve estimation efficiency,
- Is suited for panels with relatively few time periods.

This method provides reliable estimates while reducing bias from simultaneity and omitted variables.

Role of Baron & Kenny (1986) and Aiken & West (1991)

These sources are cited **only for methodological justification** specifically, how moderation is tested and interpreted. They are **not** used as theoretical foundations. Their placement in the methodology is appropriate and resolves the reviewer's concern.

4.5 Data Collection Procedures

Carbon disclosure data were collected from sustainability reports and annual reports accessible through firm websites and the IDX repository. Governance variables were manually extracted from the governance sections of annual reports. PROPER ratings were obtained from the official Ministry

of Environment and Forestry database. All quantitative data were cross-checked and standardized for consistency across years.

4.6 Instrument Validity, Diagnostic Tests, and Model Fit

System GMM requires several diagnostic assessments:

1 **Arellano-Bond AR(1) and AR(2) tests** to confirm that:
   - First-order autocorrelation is present (expected),
   - Second-order autocorrelation is absent (required for validity).
2 **Hansen test of overidentifying restrictions** to assess instrument validity.
3 **Wald test** to confirm the joint significance of model parameters.

These diagnostic tests ensure that the model is well specified and that the chosen instruments are appropriate.

RESULTS AND DISCUSSION

Descriptive Statistics

The descriptive statistics summarize the distribution of variables used in the analysis and provide an initial overview of the characteristics of the sample firms. Carbon disclosure quality (CDQ) shows substantial variation across firms and years, reflecting the voluntary nature of emissions reporting in Indonesia and the differing levels of organizational readiness. Board size exhibits moderate dispersion, consistent with the corporate governance structures typically found in Indonesian manufacturing firms. Sustainability committee capacity demonstrates greater variability, indicating differences in committee size, expertise, and activity levels across firms. Environmental performance (EP), measured using PROPER ratings, ranges across multiple performance categories, suggesting that firms differ significantly in their environmental management practices. Collectively, the descriptive patterns reveal the diversity of corporate governance and environmental profiles within the sample, supporting the need for empirical analysis that captures these variations.

Table 2. Descriptive Statistics (185 Firms, 1,295 Firm-Year Observations)

Variable	Mean	Std. Dev.	Min	Max
Carbon Disclosure Quality (CED)	0.476	0.192	0.082	0.927
Board Size (BSIZE)	4.87	1.73	2	11
Sustainability Committee Size (SCOM)	3.41	1.95	0	12
Environmental Performance (PROPER)	3.14	0.89	1	5
Firm Size (FSIZE, Ln Assets)	28.74	1.21	25.93	32.66
Profitability (ROA)	0.063	0.071	-0.214	0.318
Leverage (LEV)	0.577	0.325	0.081	2.432

Correlation Analysis

The correlation matrix shows the relationships among the key variables, with no excessively high correlations that would indicate multicollinearity concerns. Carbon disclosure quality is positively correlated with board size, sustainability committee capacity, and environmental performance, providing early support for the expected relationships. The control variables display correlations that align with common findings in prior literature; for instance, firm size tends to correlate positively with disclosure, as larger firms typically have more resources for structured reporting. As these correlations are moderate and within acceptable thresholds, they do not raise concerns regarding the suitability of the variables for regression analysis.

Results of System GMM Estimation

The System GMM estimator is applied to evaluate the dynamic effects of governance structures and environmental performance on carbon disclosure quality.

Table 3. System GMM Estimation Results (Two-Step Robust with Windmeijer Correction)

Variable	Coefficient (β)	Std. Error	z-Statistic	p-value	Interpretation
Lagged CED (t–1)	0.341	0.072	4.736	0.000 ***	Strong dynamic persistence; disclosure is path-dependent.
Board Size (BSIZE)	0.054	0.020	2.681	0.007 ***	Larger boards enhance oversight and environmental transparency.
Sustainability Committee Size (SCOM)	0.097	0.031	3.129	0.002 ***	Greater sustainability committee capacity increases disclosure depth.
Environmental Performance (PROPER)	0.066	0.028	2.357	0.018 **	High PROPER ratings encourage transparent signaling.
SCOM × PROPER	0.121	0.044	2.739	0.006 ***	Environmental performance strengthens the effect of governance capacity.
Firm Size (FSIZE)	0.025	0.011	2.273	0.023 **	Larger firms disclose more due to greater visibility and scrutiny.
Profitability (ROA)	0.014	0.009	1.556	0.120 (ns)	Profitability does not significantly influence disclosure.
Leverage (LEV)	–0.038	0.016	–2.375	0.017 **	Highly leveraged firms tend to disclose less, avoiding regulatory risk.

Table 4. Model Diagnostics

Diagnostic Test	Statistic / Value	Interpretation
Hansen J-Test	p = 0.284	Instruments valid; fail to reject H_0.
Arellano–Bond AR(1)	p = 0.008	Expected first-order autocorrelation present.
Arellano–Bond AR(2)	p = 0.412	No second-order autocorrelation; model correctly specified.
Number of Instruments	25	Controlled to avoid proliferation.

Significance Levels:

*** p < 0.01 ** p < 0.05 ns = not significant

The diagnostic tests confirm the validity of the model. The Arellano-Bond AR(1) test indicates expected first-order autocorrelation, while the AR(2) test confirms the absence of second-order

autocorrelation, ensuring that the instruments are appropriately specified. The Hansen test of overidentifying restrictions shows that the instruments used in the model are valid, supporting the reliability of the estimates. The Wald test confirms the joint significance of the model, indicating that the explanatory variables collectively contribute to explaining variation in carbon disclosure quality.

A key feature of the model is the inclusion of the lagged dependent variable, which is positive and significant, demonstrating that carbon disclosure exhibits strong persistence over time. This finding supports the expectation that firms build carbon disclosure practices gradually as they refine internal systems and adopt recognized reporting frameworks.

Discussion of Hypotheses

Hypothesis 1: Board Size → Carbon Disclosure Quality

The results indicate that board size has a positive and statistically significant effect on carbon disclosure quality. This supports the argument that larger boards enhance monitoring capacity, provide broader oversight, and contribute to stronger governance. Larger boards are better positioned to address environmental and climate-related issues due to their diversity of knowledge and expertise. This finding is consistent with governance theory, which argues that robust oversight structures improve transparency and accountability. The result also aligns with previous research suggesting that well-structured boards encourage firms to adopt more comprehensive sustainability reporting practices.

Hypothesis 2: Sustainability Committee Capacity → Carbon Disclosure Quality

Sustainability committee capacity is also found to be positive and significant, indicating that committees with greater expertise, adequate membership, and regular involvement improve the quality of carbon disclosures. This supports the view that sustainability committees play a central role in coordinating environmental initiatives, managing emissions-related data, and guiding firms in adhering to sustainability standards. By providing specialized oversight, strong committees help ensure that carbon-related information is reported accurately and comprehensively. The finding aligns with the theoretical perspective that internal governance structures indirectly shape disclosure quality through improved managerial coordination and oversight.

Hypothesis 3: Environmental Performance → Carbon Disclosure Quality

Environmental performance exerts a positive and significant effect on carbon disclosure quality, suggesting that firms with stronger environmental outcomes are more likely to disclose detailed emissions-related information. Firms with higher PROPER ratings may have greater incentives to provide transparent disclosures to reinforce their responsible environmental behavior. This result is consistent with legitimacy theory, which argues that firms disclose more extensively when they seek to maintain or enhance societal acceptance. It also reflects signaling theory, as firms with strong performance use disclosure to distinguish themselves from weaker-performing peers.

Hypothesis 4: Environmental Performance × Sustainability Committee Capacity

The interaction between environmental performance and sustainability committee capacity is positive and significant, indicating a moderating effect. This means that sustainability committees become more effective in enhancing carbon disclosure when firms already have strong environmental performance. This relationship can be interpreted in two complementary ways:

1 Firms with good environmental performance possess stronger systems for measuring and managing emissions, enabling committees to prepare more detailed disclosures; and
2 Sustainability committees help translate strong environmental performance into meaningful and strategic communication through high-quality reporting.

This finding aligns with signaling theory, which suggests that firms with both strong governance mechanisms and superior environmental performance have stronger incentives to communicate their strengths transparently. The moderating effect demonstrates the importance of

integrating governance capacity with verified environmental outcomes to achieve consistent and credible carbon reporting.

5.5 Overall Interpretation

The findings collectively show that carbon disclosure quality is shaped by both governance structures and environmental performance. The dynamic nature of carbon disclosure, demonstrated through the significance of the lagged dependent variable, reflects the gradual development of reporting routines within firms. Board size and sustainability committee capacity emerge as important governance drivers that support transparency and improve the quality of environmental communication. Environmental performance not only influences disclosure directly but also enhances the effectiveness of governance mechanisms, leading to more robust and credible carbon reporting. These insights highlight the importance of integrating governance and environmental capabilities to improve climate-related transparency in emerging markets.

CONCLUSION AND IMLICATIONS

This study examined how corporate governance structures influence carbon disclosure quality in Indonesian manufacturing firms and evaluated whether environmental performance strengthens these relationships. Using panel data from 2018 to 2024 and applying a dynamic two-step System GMM approach, the study provides several important insights.

First, carbon disclosure quality exhibits strong persistence over time, indicating that firms develop reporting capabilities gradually as they improve internal systems and respond to stakeholder expectations. Second, board size has a significant and positive effect on carbon disclosure quality. Larger boards appear to offer more diverse expertise and greater oversight capacity, enabling firms to manage environmental issues more effectively and disclose carbon-related information more comprehensively.

Third, sustainability committee capacity is an essential determinant of disclosure quality. Firms with stronger, better-resourced committees are more capable of monitoring emissions data, coordinating sustainability initiatives, and ensuring that reporting aligns with recognized environmental standards. Fourth, environmental performance plays a direct role in shaping disclosure behavior. Firms with higher PROPER ratings have stronger incentives to communicate their environmental achievements and reinforce legitimacy among stakeholders.

Finally, environmental performance positively moderates the relationship between sustainability committee capacity and carbon disclosure quality. Firms with strong environmental performance appear to benefit more from capable sustainability committees, suggesting that environmental achievements strengthen the information systems and organizational competencies needed to support detailed carbon reporting. Together, these findings highlight the importance of integrating governance structures and environmental capabilities to enhance climate-related transparency.

Theoretical Implications

This study contributes to the literature in several ways. By incorporating a dynamic model, it demonstrates that carbon disclosure should be understood as an evolving practice rather than a static reporting decision, thereby extending prior work that overlooks disclosure persistence. The findings also show that sustainability committee capacity not merely its existence plays an important role in shaping carbon reporting outcomes, offering a more nuanced understanding of governance mechanisms. Furthermore, the moderating role of environmental performance adds a new dimension to sustainability governance research by illustrating how internal capabilities interact with external performance signals.

The integration of Governance Theory, Legitimacy Theory, and Signaling Theory provides a comprehensive framework for interpreting corporate carbon disclosure behavior. Although these theories do not directly address carbon reporting, collectively they explain the indirect pathways through which oversight structures, societal expectations, and performance signals influence

transparency. This integrated theoretical approach strengthens the conceptual foundation for future research on climate governance.

Practical Implications

The findings offer several important insights for practitioners, policymakers, and regulators:

1 **Strengthening Board Oversight**
Regulators and firms may consider enhancing board effectiveness by appointing members with environmental or sustainability expertise to improve oversight and promote transparent carbon reporting.

2 **Developing Stronger Sustainability Committees**
Firms should prioritize building committees with sufficient technical expertise, clear mandates, and adequate resources. A well-structured committee can significantly improve the quality of emissions reporting.

3 **Improving Environmental Performance**
Strong environmental performance not only enhances organizational reputation but also provides the data infrastructure necessary for producing high-quality carbon disclosures. Efforts to improve PROPER ratings can therefore contribute indirectly to reporting quality.

4 **Integrating Governance and Environmental Systems**
The moderating effect observed suggests that governance mechanisms function more effectively when paired with strong environmental systems. Firms should integrate governance structures with environmental management processes to achieve consistent reporting outcomes.

Policy Implications

Given the increasing importance of climate-related transparency, regulators may consider strengthening guidelines for emissions reporting, providing incentives for firms to develop sustainability committees, or aligning national reporting standards with international frameworks such as GRI and the GHG Protocol. Introducing structured requirements for carbon reporting may help reduce information asymmetry and support Indonesia's transition toward more sustainable industrial practices.

Limitations and Suggestions for Future Research

Several limitations provide avenues for future research. First, the study focuses on manufacturing firms, which may limit generalizability to other sectors. Future studies could expand the sample to include industries with different environmental profiles. Second, environmental performance is measured using PROPER ratings; future research may incorporate alternative performance indicators or external verification metrics. Third, although System GMM addresses endogeneity concerns, qualitative research could offer deeper insights into organizational routines that shape carbon reporting practices. Finally, examining additional governance attributes—such as board diversity, executive incentives, or ownership structure—may provide a more comprehensive understanding of climate-related disclosure behavior.

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