“The impact of board governance effectiveness on carbon disclosure in the banking sector”

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THE IMPACT OF BOARD GOVERNANCE EFFECTIVENESS ON CARBON DISCLOSURE IN THE BANKING SECTOR

Abstract

Climate-related risks have intensified the demand for transparency in the banking sector, particularly with respect to carbon-related information disclosed to stakeholders. In emerging economies, where climate disclosure remains largely voluntary, internal governance mechanisms are expected to play a decisive role in shaping reporting practices. The aim of this study is to examine the relationship between board governance effectiveness and carbon emission disclosure in the ASEAN banking sector. The object of the study is listed commercial banks operating in six ASEAN countries over the period 2014–2023. The analysis is based on panel data and employs fixed-effects and Tobit regression models to account for unobserved heterogeneity and the bounded nature of disclosure scores. The results indicate that board governance effectiveness is positively and statistically associated with carbon emission disclosure. Accordingly, the within R-squared value for the fixed-effects model is 23.5%, while the pseudo R-squared for the Tobit model is 55%, indicating strong explanatory power of both specifications. Economically, a one-point increase in the Board Effectiveness Score corresponds to an increase of 2.630 units in carbon emission disclosure in the fixed-effects model and 4.550 units in the Tobit specification, indicating economically meaningful improvements in disclosure intensity. In addition, bank size, age, profitability, and eco-innovation activity are found to be positively related to disclosure levels. The results remain robust across alternative specifications, including panel quantile regression, panel logit estimation, and two-step system generalized method of moments.

Keywords corporate governance, sustainable development goals, climate change

JEL Classification G34, Q56, G21, M41

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INTRODUCTION

Recent risk dynamics have reshaped corporate operations and the global economy, with climate change emerging as a major source of regulatory, financial, and reputational risk (Kutlu Furtuna & Sönmez, 2024). Firms are increasingly exposed to climate-related transition and liability risks, prompting growing demands from regulators, investors, and civil society for transparent disclosure of carbon-related information as a mechanism for assessing environmental exposure and accountability (Oyewo et al., 2024). International initiatives such as the Kyoto Protocol and the Paris Agreement further reinforce the role of carbon transparency as a cornerstone of global climate governance (Nuber & Velte, 2021). Despite these pressures, substantial variation persists in firms' environmental responsibility, and in many emerging economies – including those in the ASEAN region – carbon emission disclosure remains largely voluntary due to fragmented or underdeveloped regulatory frameworks (Oussii & Jeriji, 2024).

In such institutional environments, corporate governance assumes heightened importance. Boards of directors are no longer confined to

traditional financial oversight but are increasingly expected to supervise non-financial risks, including climate-related exposure and disclosure practices (Adu et al., 2024). Where formal regulatory enforcement is weak or inconsistent, internal governance mechanisms may act as substitutes for external control by shaping transparency, monitoring managerial behavior, and signaling organizational legitimacy (Tingbani et al., 2020). However, empirical evidence from developing and emerging economies remains limited, and existing findings on the effectiveness of board governance in influencing carbon emission disclosure are mixed and often inconclusive, creating uncertainty regarding the capacity of governance mechanisms to discipline disclosure behavior under voluntary reporting regimes (Ali et al., 2024; Caby et al., 2024).

The ASEAN context illustrates this challenge particularly clearly. Regional greenhouse gas emissions are primarily driven by energy production, industrial activity, agriculture, and transport (Anwar et al., 2020). Although the banking sector contributes only marginally to direct operational emissions, its indirect impact through financed emissions is substantial, reflecting banks' central role in allocating capital to carbon-intensive sectors (ADB, 2024; World Bank, 2023, 2024). As a result, carbon emission disclosure in banking reflects governance quality and transparency regarding climate-related financial risk exposure rather than operational environmental performance (Nguyen et al., 2025).

Although prior research has examined board characteristics and environmental disclosure, most studies focus on non-financial industries and assess governance attributes in isolation. Such fragmented approaches offer limited insight into how boards function collectively when addressing complex, forward-looking disclosure decisions in financial institutions. This limitation is particularly consequential in emerging economies, where voluntary disclosure regimes prevail, and internal governance mechanisms are expected to compensate for regulatory gaps. Consequently, the conditions under which board governance effectiveness enhances carbon emission disclosure in ASEAN banking systems remain insufficiently understood.

1. LITERATURE REVIEW

Climate change is increasingly recognized as a systemic risk to economic activity and financial stability, drawing growing attention to the role of financial institutions in climate mitigation and transparency (Fan et al., 2023). While banks generate relatively limited direct greenhouse gas emissions, their lending and investment decisions shape the carbon intensity of the real economy through financed emissions. In regions such as ASEAN, where climate-related disclosure remains predominantly voluntary and regulatory enforcement is uneven, internal governance mechanisms are expected to play a central role in disciplining carbon emission disclosure practices (Radu et al., 2022; Saadah et al., 2024; Furtuna & Sönmez, 2024).

A substantial body of international research examines the relationship between corporate governance and carbon emission disclosure, particularly in voluntary reporting environments. Across both emerging and developed economies, firm characteristics such as size, profitability, and public visibility are consistently associated with higher levels of environmental disclosure (Bose et al., 2018). However, empirical evidence regarding governance mechanisms remains mixed. While several studies report that board monitoring structures enhance carbon transparency, others document weak, insignificant, or context-dependent effects, reflecting institutional differences across countries and disclosure regimes (Kılıç & Kuzey, 2018; Chakraborty & Dey, 2023; Park et al., 2023).

Recent research has increasingly focused on board diversity and governance substructures as drivers of disclosure quality. Gender-diverse boards, female leadership, and specialized audit or sustainability committees are frequently associated with higher-quality carbon disclosure and greater transparency (Lahyani, 2022; Fan et al., 2023; Saadah et al., 2024). At the same time, findings related to other governance attributes – such as board independence, size, tenure, or meeting fre-

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quency – remain inconsistent (Al-Okaily et al., 2022; Al-Tahat et al., 2025). This pattern suggests that examining individual governance mechanisms in isolation may provide only partial insight into disclosure behavior (Ben-Amar et al., 2017; Bedi & Singh, 2024).

Beyond disclosure, another stream of literature investigates the relationship between corporate governance and actual carbon performance, including emission reduction and environmental innovation. Evidence from high-emission sectors such as manufacturing and energy indicates that effective governance structures can constrain emissions and promote sustainability-oriented investments (Elsayih et al., 2021; Konadu et al., 2022; Khatri, 2024). However, these findings are not directly transferable to the banking sector, where emissions are primarily embedded in financing activities rather than production processes, and where disclosure serves a different informational function (Almustafa et al., 2023).

In the banking context, carbon emission disclosure operates less as a measure of operational environmental performance and more as a governance-driven transparency mechanism that signals exposure to climate-related financial risks. This distinction is particularly relevant in ASEAN economies, where disclosure remains largely voluntary and governance mechanisms may substitute for weak regulatory oversight (Handoyo et al., 2024; Furtuna & Sönmez, 2024; Kurnia et al., 2025). Accordingly, banks' disclosure decisions are likely to reflect internal governance effectiveness rather than external regulatory compulsion (Al-Okaily et al., 2023).

Theoretical perspectives provide further support for this view. Agency theory suggests that effective boards reduce information asymmetry and managerial opportunism by strengthening monitoring and transparency (Chakraborty & Dey, 2023). Stakeholder theory emphasizes disclosure as a response to pressures from investors, regulators, and civil society seeking accountability for environmental impacts (Al-Tahat et al., 2025; Radu et al., 2022). Resource dependence theory further argues that diverse and experienced boards enhance access to external knowledge and legitimacy, facilitating the integration of climate considerations into strategic decision-making (Velte, 2025; Saadah et al., 2024). Collectively, these frameworks imply that carbon disclosure outcomes depend on the overall effectiveness of board governance rather than on isolated structural characteristics.

Despite the expanding literature, most empirical studies continue to analyze governance mechanisms separately – such as gender diversity, board independence, or committee structures – and often within single-country or non-financial firm settings (Alshdaifat et al., 2024; Gull et al., 2025). This fragmented approach has produced mixed and sometimes contradictory findings, obscuring the cumulative impact of governance arrangements on carbon emission disclosure (Chithambo & Tauringana, 2017; Bedi & Singh, 2024). Recent scholarship increasingly calls for composite governance measures that capture board effectiveness holistically by integrating multiple governance dimensions into a single construct (Velte, 2025).

However, such integrated approaches remain rare in banking research and are largely absent in ASEAN-focused studies, where financed emissions substantially exceed operational emissions and governance-led disclosure may play a pivotal role in regional decarbonization trajectories. Overall, prior research establishes that corporate governance is relevant for carbon emission disclosure, particularly in voluntary reporting regimes. Nevertheless, the literature remains fragmented, sectorally biased toward non-financial firms, and focused primarily on individual governance attributes rather than overall board effectiveness.

Accordingly, the purpose of this study is to examine how board governance effectiveness, measured through a composite Board Effectiveness Score, influences carbon emission disclosure in the ASEAN banking sector.

2. METHOD

2.1. Sample selection and data collection

The study involved banks from six ASEAN countries: Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam. These coun-

Table 1. Study sample from ASEAN countries

Country	Total banks	%	Yearly Obs.	Stock Exchange
Indonesia	37	0.203	370	IDX
Philippine	29	0.159	290	PSE
Malaysia	30	0.165	300	Bursa Malaysia
Singapore	27	0.148	270	SGX
Thailand	28	0.154	280	SET
Vietnam	31	0.171	310	HOSE
Total	182	100%	1820	–

tries play a critical role in combating climate change due to their high vulnerability to rising sea levels, extreme weather events, and biodiversity loss. Below are the ASEAN members who captured their sustainability efforts and social cost impacts through reports from 2014 to 2023. A balanced dataset was utilized to create the final sample, comprising 182 banks and 1,820 annual observations, as illustrated in Table 1. Following the methodologies used by Liu et al. (2023), our data sources for carbon disclosure, governance attributes, and bank characteristics were obtained from Refinitiv DataStream.

2.2. Research model

A panel data regression model is engaged to investigate the relationship between carbon emission disclosures and board effectiveness score among a sample of ASEAN-listed banks. Our dependent variable is carbon emission disclosure, measured using CDP reports extracted from the Refinitiv DataStream (see Table 2). This study relies on these data for several reasons (Ardianto et al., 2024). First, CDP reports are considered the most reliable and credible source for prior studies related to carbon emission disclosure (Abbasi et al., 2024). Second, they provide standardized data, facilitating comparisons across various industries and regions.

The primary independent variable is the board effectiveness score, which consists of seven relevant board factors, including board gender diversity, board size, board independence, board meetings, board experience, board tenure, and environmental committees. Each of these factors has been seen to correlate with carbon emission disclosure in prior studies. When measuring the composite board effectiveness score, each non-binary variable is transformed into a binary form by assigning 1 to the variable if it is greater than or equal to the median across all samples and assigning zero otherwise. Overall, the B_Effectiveness Score is the total of the seven indicators, ranging from zero to seven. As shown in previous studies, a higher score typically indicates a higher board effectiveness score.

Furthermore, we have incorporated several bank-specific control variables based on previous literature (Kutlu Furtuna & Sönmez, 2024; Saadah et al., 2024). Bank characteristics include eco-innovation score, profitability, size, age, and financial leverage. The eco-innovation score (EIS) reflects the bank's commitment to eco-innovation (Mansour et al., 2025), which may naturally impact its carbon emission disclosures. Carbon reporting can be costly for businesses due to the resources required for data collection. We use profitability (Return on Equity – ROE) and financial leverage (FLEV) to illustrate the financial condition of banks. Additionally, mature banks are more likely to disclose climate-related concerns. Due to their greater visibility to stakeholders, larger banks are expected to provide more information on carbon emission disclosure. Therefore, we control for bank size and age (BSIZE, BAGE). Accordingly, the study's quantitative research design employs the following models:

Fixed Effects Model

$$\begin{aligned} CED_{i,t} &= \beta_0 + \beta_1 B\_Effectiveness\ Score_{i,t} \\ &+ \beta_2 EIS_{i,t} + \beta_3 ROE_{i,t} + \beta_4 BAGE_{i,t} \\ &+ \beta 5 BSIZE_{i,t} + \beta 6 FLEV_{i,t} \\ &+ \gamma_1 Year\ Fixed\ Effects + \varepsilon_{i,t}, \end{aligned} \quad (1)$$

where *CED* denotes carbon emission disclosure for bank i in year *t*, γ_1 represents the time-invariant bank-specific effects, and $\varepsilon_{i,t}$ indicates the idiosyncratic error term.

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Tobit Model

$$CED^{*}_{i,t} = \beta_0 + \beta_1 B\_Effectiveness\ Score_{i,t} + \beta_2 EIS_{i,t} + \beta_3 ROE_{i,t} + \beta_4 BAGE_{i,t} + \beta_5 BSIZE_{i,t} + \beta_6 FLEV_{i,t} + \gamma_1 Year\ Fixed\ Effects + \varepsilon_{i,t}, \quad (2)$$

where $CED^{*}_{i,t}$ is the latent variable representing the true but unobserved level of carbon emission disclosure, and $CED_{i,t}$ is the observed censored variable bounded between 0 and 100.

In this study, i represents individual banks (1 to 182), while t denotes the study period from 2014 to 2023 across the ASEAN-6 Banking Sector. Entirely variable definitions are in Table 2.

Panel data analysis was used to strengthen the robustness of the findings, reducing potential multicollinearity issues among instructive variables and increasing the reliability of the results (Mansour et al., 2024). Furthermore, the panel data framework allows for controlling bank-level heterogeneity, thereby minimizing biases in the estimations (Alshdaifat et al., 2024; Bani Atta, 2025; Saleh & Mansour, 2024). In addition, the Tobit model effectively analyzes carbon emission disclosure, managing the censored data typical in environmental metrics. Carbon emission disclosure values range from 0% to 100%, with banks reporting zero emissions, leading to data clustering. Traditional models, such as OLS, produce biased estimates because they overlook this censorship. The Tobit model addresses this issue by modeling both the probability and extent of disclosure, which results in more accurate parameter estimates. It also enables us to navigate carbon emission disclosure data limitations, such as censoring and boundary effects, ensuring valid and reliable relationships between board effectiveness and carbon disclosure.

3. RESULTS

3.1. Descriptive statistics summary

Table 3 presents the descriptive statistics for the variables in this study. Winsorization was applied at the 1st and 99th percentiles to mitigate extreme values (Saleh et al., 2025). This analysis enhances the understanding and interpretation of the dataset.

Table 2. Variable definitions

Variables	Abbreviation	Definitions
Dependent variable		
Carbon Emission Disclosure	CED	The carbon disclosure score, presented as a percentage, is reported by the Carbon Disclosure Project (CDP)
Independent variables		
Board effectiveness Score	B_Effectiveness Score	The sum of the seven characteristics of the board of directors ranges from 0 to 7, with a higher score indicating greater bank board effectiveness
Control Variables		
Eco- Innovation Score	EIS	A score exhibits the bank's success in using technology and sustainable products to create new markets, thus lowering environmental costs and customer burdens.
Operating Performance	ROE	Log Net income/total equities
Bank age	BAGE	Calculated using the natural logarithm of the years since the bank was established
Bank size	BSIZE	Calculated using the natural logarithm of total bank assets
Financial Leverage	FLEV	Total debt/total assets

Table 3. Descriptive statistics

Variables	N	Mean	Median	Min	Max	SD	Skewness	Kurtosis
(1) CED	1820	52.106	53.66	0	97.435	19.516	-0.237	1.910
(2)B_Effectiveness Score	1820	5.651	5.5	0	7	0.137	1.097	3.232
(3) EIS	1820	0.455	0.45	0.113	0.847	2.466	0.982	2.287
(4) ROE	1820	0.129	0.130	0.057	0.459	0.172	0.943	3.357
(5) BAGE	1820	1.255	1.300	1.755	2.245	0.231	0.986	3.723
(6) BSIZE	1820	11.596	11.551	9.279	13.619	0.719	0.127	2.881
(7) FLEV	1820	0.657	0.670	0.459	0.952	0.355	1.351	3.276

The mean carbon emission disclosure is 52.106%, with a median of 53.66% and a high standard deviation (SD = 19.516), indicating substantial variability. The distribution is slightly left-skewed (–0.237), suggesting that most banks disclose carbon emissions. The B_Effectiveness Score averages 5.651, with a positive skew (1.097), indicating that some banks have highly effective boards. The EIS has a mean of 0.455, with a high SD (2.466), reflecting variability in green innovation efforts. ROE averages 12.9%, showing diverse profitability across banks. BAGE has a mean of 1.255, with slight positive skewness, suggesting maturity differences. The average BSIZE is 11.596, with low dispersion. FLEV stands at 65.7%, with high skewness (1.351), indicating varying capital structures among banks. The diverse carbon emission disclosure levels and governance variations highlight differences in regulatory compliance, voluntary reporting, and sustainability strategies within the banking sector.

3.2. Bivariate correlations

Table 4 presents the pairwise correlation coefficients among CG characteristics, carbon emission disclosure, and control variables for 182 banks from 2014 to 2023. The results show that carbon emission disclosure is significantly and positively correlated with Board Effectiveness Score (0.147, $p < 0.05$), Eco-Innovation Score (EIS) (0.448, $p < 0.05$), and Bank Size (BSIZE) (0.480, $p < 0.05$), indicating that well-governed, innovative, and larger banks are more likely to engage in transparent carbon disclosure.

Additionally, the strong correlation between carbon emission disclosure and EIS suggests that banks prioritizing eco-innovation emphasize carbon disclosure. Financial leverage (FLEV) exhibits a positive but weak correlation with carbon emission disclosure (0.046, $p < 0.05$), implying that banks with higher debt levels may be slightly inclined toward carbon reporting. Bank Age (BAGE) (0.184, $p < 0.05$) and Return on Equity (ROE) (0.187, $p < 0.05$) also correlate positively with carbon emission disclosure, suggesting that older and more profitable banks tend to disclose more environmental information. The correlation matrix further confirms that multicollinearity is not a concern, as no variables display excessively high correlations (Alhasnawi et al., 2025). Overall, these findings underscore the influence of CG, financial factors, and environmental strategies on carbon disclosure practices in the banking sector.

3.3. Variance inflation factor

Table 5 presents the Variance Inflation Factor (VIF) values for all independent variables, ranging from 1.015 to 1.117. These values indicate low multicollinearity concerns (Mansour et al., 2024), as they remain below the threshold of 5. The mean VIF is 1.051, confirming stable regression estimates and reliable interpretations.

Table 4. Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) CED	1.000	–	–	–	–	–	–
	–	–	–	–	–	–	–
(2) B_Effectiveness Score	0.147*	1.000	–	–	–	–	–
	(0.000)	–	–	–	–	–	–
(3) EIS	0.448*	–0.189*	1.000	–	–	–	–
	(0.000)	(0.000)	–	–	–	–	–
(4) ROE	0.187*	–0.037	–0.020	1.000	–	–	–
	(0.000)	(0.058)	(0.313)	–	–	–	–
(5) BAGE	0.184*	0.002	0.209*	0.105*	1.000	–	–
	(0.000)	(0.921)	(0.000)	(0.000)	–	–	–
(6) BSIZE	0.480*	0.045*	0.108*	0.102*	0.084*	1.000	–
	(0.000)	(0.022)	(0.000)	(0.000)	(0.000)	–	–
(7) FLEV	0.046*	–0.047*	0.021	–0.012	–0.028	–0.096*	1.000
	(0.019)	(0.016)	(0.285)	(0.538)	(0.146)	(0.000)	–

Note: * $p < 0.05$.

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Table 5. Variance inflation factor

Independent variables	VIF	1/VIF
B_Effectiveness Score	1.045	.957
EIS	1.117	.895
ROE	1.036	.965
BAGE	1.058	.945
BSIZE	1.037	.964
FLEV	1.015	.985
Mean VIF	1.051	–

3.4. Multivariate regression results

The empirical analysis is based on a panel of 182 banks with 1,820 bank-year observations. Table 6 reports the baseline regression results from the fixed-effects model and the Tobit model.

Table 6. Results of baseline regression models

Variables	Carbon emission disclosure	
	Fixed Effects Results	Tobit Results
B_Effectiveness Score	2.630***	4.550***
	(0.095)	(0.154)
EIS	13.520***	7.110***
	(1.089)	(2.178)
ROE	3.060**	2.330**
	(3.792)	(5.078)
BAGE	4.280***	3.080***
	(4.053)	(6.063)
BSIZE	13.140***	8.780***
	(1.162)	(1.889)
FLEV	4.220***	5.980***
	(0.026)	(0.019)
Constant	11.450***	10.04***
	(13.449)	(1.903)
Within R-squared	23.50%	-
Pseudo R-squared	-	55%
N	182	182
Obs.	1820	1820
Hausman Test	44.06***	-

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Across both specifications, the Board Effectiveness Score is positive and statistically significant. In the fixed-effects model, the coefficient equals 2.630 ($p < 0.01$), while in the Tobit model, the coefficient equals 4.550 ($p < 0.01$). Economically, this indicates that a one-unit increase in board effectiveness is associated with an increase of 2.630 units in carbon emission disclosure under the fixed-effects specification and 4.550 units under the Tobit specification. These results are consistent with the study's main argument regarding the role of board governance effectiveness in shaping carbon emission disclosure.

Regarding model fit, the fixed-effects model reports a within R-squared of 23.5%, while the Tobit model reports a pseudo R-squared of 55%, indicating that the explanatory variables account for a substantial share of the variation in carbon emission disclosure. The Hausman test statistic equals 44.06 ($p < 0.01$), supporting the use of the fixed-effects estimator for the baseline panel specification.

Among control variables, Eco-Innovation Score (EIS) is positive and statistically significant in both models (13.520, $p < 0.01$ in fixed effects; 7.110, $p < 0.01$ in Tobit). Return on Equity (ROE) is also positive and significant (3.060, $p < 0.05$; 2.330, $p < 0.05$). Bank age (BAGE) shows positive and significant coefficients (4.280, $p < 0.01$; 3.080, $p < 0.01$). Bank size (BSIZE) is positive and significant (13.140, $p < 0.01$; 8.780, $p < 0.01$). Financial leverage (FLEV) is positive and significant (4.220, $p < 0.01$; 5.980, $p < 0.01$). Overall, the baseline results indicate consistent coefficient signs and statistical significance across the fixed-effects and Tobit estimations.

3.5. Additional analysis

To examine whether the relationship between board governance effectiveness and carbon emission disclosure varies across different disclosure levels, panel quantile regression is employed, following prior governance-disclosure studies that emphasize heterogeneity in sustainability reporting behavior (Mansour et al., 2025; Karim et al., 2021; Guo et al., 2024). This approach allows the estimation of effects at different points of the conditional distribution of carbon emission disclosure, providing insights that cannot be captured by mean-based estimators (Koenker & Bassett, 1978). Quantile regressions are estimated at the 25th, 50th (median), and 75th percentiles, corresponding to banks with low, moderate, and high disclosure levels, respectively.

Table 7 reports the results. Across all quantiles, the Board Effectiveness Score remains positive and statistically significant. Specifically, the estimated coefficients equal 5.912 ($p < 0.01$) at the 25th per-

centile, 7.045 ($p < 0.01$) at the median, and 6.248 ($p < 0.01$) at the 75th percentile. These findings indicate that stronger board governance is consistently associated with higher carbon emission disclosure across the entire distribution of disclosure intensity, with the largest effect observed among banks with moderate disclosure levels, consistent with evidence reported in prior governance–carbon disclosure studies (Chakraborty & Dey, 2023; Saadah et al., 2024).

Table 7. Quantile regression

Quantile regression	Carbon emission disclosure		
	0.25	0.5	0.75
B_Effectiveness Score	5.912***	7.045***	6.248***
	(0.58)	(0.615)	(0.702)
EIS	2.015***	1.785***	1.023***
	(0.215)	(0.229)	(0.261)
ROE	14.112***	26.332***	21.487***
	(4.92)	(5.312)	(6.089)
BAGE	12.755***	6.611**	11.104***
	(2.705)	(2.911)	(3.356)
BSIZE	13.278***	12.894***	10.764***
	(0.825)	(0.889)	(1.025)
FLEV	2.912*	3.112*	2.501
	(1.58)	(1.689)	(1.945)
Constant	–2.00***	–1.25***	–0.50***
	(1.512)	(2.125)	(3.250)
N	1820	1820	1820
Pseudo R^2	33.61%	30.50%	22.85%

Note: *** p < 0.01, ** p < 0.05, * p < 0.1.

Among the control variables, eco-innovation score, return on equity, bank age, and bank size exhibit positive and significant effects across most quantiles, although their magnitudes vary. Financial performance and firm characteristics appear to exert stronger influences at lower and median disclosure levels, while their effects become relatively smaller among banks with already high disclosure intensity, in line with earlier findings on firm heterogeneity in sustainability disclosure (Ben-Amar et al., 2017; Park et al., 2023). The pseudo R-squared values range from 22.85% to 33.61%, indicating satisfactory explanatory power across quantiles. Overall, the quantile regression results are consistent with the baseline estimates and reinforce the robustness of the positive association between board governance effectiveness and carbon emission disclosure.

3.6. Sensitivity test

To further validate the robustness of the baseline findings, an alternative measure of carbon emission disclosure is employed. Following prior studies (Ben-Amar et al., 2017; Kutlu Furtuna & Sönmez, 2024; Park et al., 2023), a binary indicator is constructed that equals 1 if a bank discloses carbon emission-related information and 0 otherwise. A fixed-effects panel logit model is then estimated, with year dummy variables included to control for time effects, consistent with earlier governance-disclosure research (Chithambo & Tauringana, 2017).

Table 8. Results of panel logit regression – fixed-effects with the Hausman test

Variables	Carbon emission disclosure
B_Effectiveness Score	1.037***
	(5.58)
EIS	1.351***
	(7.96)
ROE	1.373*
	(2.46)
BAGE	2.055***
	(3.97)
BSIZE	1.431***
	(9.65)
FLEV	0.494*
	(1.81)
Year Dummy Variables	Included
Hausman Chi^2 Test	442.143***
N	182

Note: Significance levels: * p < 0.05, ** p < 0.01, *** p < 0.001. t-statistics in parentheses.

The results are presented in Table 8. The Board Effectiveness Score remains positive and statistically significant (coefficient = 1.037, $p < 0.01$), indicating that stronger board governance increases the likelihood of carbon emission disclosure. Control variables largely preserve their signs and significance levels, with eco-innovation score, bank size, bank age, and profitability positively associated with disclosure, while financial leverage exhibits a weaker effect. The Hausman chi-square statistic ($\chi^2 = 442.143$, $p < 0.01$) supports the fixed-effects specification.

Overall, the panel logit results are consistent with the baseline fixed-effects and Tobit estimates, confirming that the main findings are not sensitive to

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the measurement of carbon emission disclosure. This additional analysis strengthens the credibility of the results and mitigates concerns related to potential measurement bias, in line with robustness approaches adopted in prior carbon disclosure studies (Ali et al., 2024; Saadah et al., 2024).

3.7. Further analysis

Prior research suggests that the relationship between board governance and carbon emission disclosure may be subject to endogeneity concerns, arising from omitted variables, simultaneity, or reverse causality (Muktadir-Al-Mukit & Bhaiyat, 2024). To address these concerns, a dynamic panel system generalized method of moments (System GMM) estimator is employed, following established practices in governance and sustainability research (Abbasi et al., 2024; Nuber & Velte, 2021).

Table 9. Results of dynamic panel GMM estimators

Variables	Carbon emission disclosure
Lag. CED	0.518***
	(0.182)
B_Effectiveness Score	0.268***
	(0.037)
EIS	0.268***
	(0.058)
ROE	0.631***
	(0.195)
BAGE	0.072***
	(0.017)
BSIZE	4.012***
	(0.421)
FLEV	0.445*
	(1.833)
Year Dummy Variables	Included
Hausman Chi² Test	–
No. of group	182
No. of instruments	21
AR(1)	0.0006
AR(2)	0.345
Hansen J.	0.546

Note: Significance levels: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors in parentheses.

The System GMM approach allows for the inclusion of a lagged dependent variable, controls for unobserved firm-specific effects, and mitigates potential endogeneity through internal instrumentation (Mansour et al., 2024). This method is particularly suitable for panels with a relatively large number of cross-sectional units and a shorter time dimension, as in the present study. Year dummy variables are included to capture common time effects.

Table 9 reports the dynamic panel GMM estimation results. The coefficient on lagged carbon emission disclosure is positive and statistically significant (0.518, $p < 0.01$), indicating persistence in disclosure practices over time. Importantly, the Board Effectiveness Score remains positive and statistically significant (0.268, $p < 0.01$), confirming that stronger board governance continues to be associated with higher levels of carbon emission disclosure after accounting for dynamic effects and endogeneity. The control variables largely preserve their expected signs and significance levels, consistent with the baseline and robustness estimations.

Model diagnostics support the validity of the System GMM specification. The Arellano–Bond test for first-order serial correlation (AR(1)) is significant, while the second-order autocorrelation test (AR(2)) is insignificant ($p = 0.345$), indicating no second-order serial correlation in the differenced errors. The Hansen J-test is insignificant ($p = 0.546$), suggesting that the instruments are valid. In addition, the number of instruments (21) remains well below the number of groups (182), reducing concerns related to instrument proliferation.

Overall, the System GMM results corroborate the baseline fixed-effects and Tobit estimates, indicating that the positive association between board governance effectiveness and carbon emission disclosure is robust to alternative dynamic specifications and endogeneity corrections.

4. DISCUSSION

This study examines whether board governance effectiveness influences carbon emission disclosure in ASEAN-listed banks operating under predominantly voluntary reporting regimes. The results indicate that banks with higher levels of board effectiveness disclose more extensive carbon-related information, underscoring the importance of internal governance mechanisms in shaping disclosure practices when formal regulatory enforcement is limited.

These findings are broadly consistent with prior evidence linking corporate governance quality to sustainability reporting outcomes (Ali et al., 2024; Bedi & Singh, 2024). However, the present study extends this literature by demonstrating that the combined functioning of board governance mechanisms exerts a stronger and more stable influence on carbon emission disclosure than isolated board attributes. Earlier studies typically focus on single governance characteristics – such as board size, gender diversity, or specialized committees – and report mixed or context-dependent results (Tingbani et al., 2020; Saadah et al., 2024). The current evidence suggests that a holistic assessment of board effectiveness offers a clearer explanation of disclosure behavior in the banking sector, where governance decisions are collective and highly interdependent.

The positive relationship between eco-innovation activity and carbon emission disclosure is also consistent with previous research showing that organizations investing in environmentally oriented innovation tend to be more transparent about their environmental impacts (Chakraborty & Dey, 2023). In the banking context, this association likely reflects the strategic integration of sustainability considerations into lending, investment, and risk management decisions, encouraging banks to communicate climate-related risks and mitigation efforts more actively to stakeholders.

Consistent with earlier studies, bank size exhibits a positive association with carbon emission disclosure, supporting the argument that larger financial institutions face greater public visibility, stakeholder scrutiny, and reputational exposure, which incentivize more comprehensive disclosure practices (Ben-Amar et al., 2017; Krishnamurti & Velayutham, 2018). Similarly, the positive effect of bank age aligns with evidence from Liao et al. (2015), suggesting that more established banks benefit from accumulated regulatory experience and reputational capital that facilitate engagement in voluntary sustainability reporting.

In contrast, the relatively weak relationship between financial leverage and carbon emission disclosure diverges from findings reported in some non-financial sectors (Abbasi et al., 2024). This divergence may indicate that banks in ASEAN prioritize balance-sheet stability and capital adequacy considerations over discretionary climate disclosure, particularly in institutional environments characterized by regulatory heterogeneity and macroeconomic uncertainty.

From a theoretical perspective, these findings are consistent with agency theory, which posits that effective boards enhance transparency by constraining managerial discretion, and with stakeholder theory, which views carbon disclosure as a strategic response to external expectations from investors, regulators, and society. The persistence of the results across multiple robustness checks and alternative specifications strengthens confidence in these interpretations and highlights the central role of board governance effectiveness in shaping climate-related disclosure in emerging banking markets.

CONCLUSION

The purpose of this study was to examine whether board governance effectiveness influences carbon emission disclosure in the ASEAN banking sector. The findings indicate that banks characterized by stronger and more effective governance structures disclose more extensive carbon-related information, particularly when board mechanisms operate collectively rather than as isolated attributes. In addition, eco-innovation activity, bank size, and organizational maturity are positively associated with carbon emission disclosure, while financial leverage appears to play a more limited role.

These results highlight the importance of internal governance quality as a key driver of carbon transparency in banking systems operating under predominantly voluntary disclosure regimes. Enhancing board effectiveness may therefore contribute to more credible, consistent, and decision-useful climate-related disclosures, improving stakeholders' ability to assess climate-related financial risks and sustainability performance in emerging markets.

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Several avenues for future research remain. Further studies could explore whether similar governance–disclosure relationships exist in other financial sectors, such as insurance or asset management, or investigate how evolving regulatory frameworks influence the role of board governance in shaping climate transparency over time. Longitudinal analyses incorporating forthcoming climate-related reporting standards may also provide deeper insight into the persistence and broader economic implications of governance-driven carbon disclosure practices.

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USE OF AI TOOLS DECLARATION

The authors declare they have not used artificial intelligence (AI) tools in the creation of this article.

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