

The Effect of Carbon Emission Disclosure on Firm Value: The Moderating Role of Independent Commissioners in Indonesia's Energy Sector, 2022-2024

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Abstract

This quantitative descriptive study examines the effect of carbon emission disclosure on firm value and the moderating role of independent commissioners in energy sector companies listed on the Indonesia Stock Exchange during 2022-2024. Agency theory provides the analytical foundation by viewing disclosure as a mechanism that reduces information asymmetry and independent commissioners as a monitoring mechanism. Carbon disclosure was measured using an 18-item index adapted from Choi et al. (2013), firm value was proxied by Tobin's Q, independent commissioners were measured by their proportion on the board, and firm size was included as a control variable. The initial sample comprised 61 companies and 183 firm-year observations. Six extreme Tobin's Q observations identified using the mean ± 3 standard deviations criterion were excluded, resulting in 177 observations from 59 companies. Panel-data regression and moderated regression analysis were estimated using a random-effects model with firm-clustered standard errors. Carbon emission disclosure had a positive and significant effect on firm value ($\beta = 0.6192$; $p = 0.024$). Predictive margins showed that Tobin's Q increased from 1.2836 at low disclosure to 1.4556 at high disclosure, a significant difference of 0.1720. The interaction between disclosure and independent commissioners was positive but insignificant ($\beta = 1.3441$; $p = 0.549$). Thus, disclosure appears to reduce information asymmetry and improve market valuation, while the formal proportion of independent commissioners does not by itself strengthen that relationship.

INTRODUCTION

Climate change has become an increasingly important corporate issue because greenhouse-gas emissions create environmental, regulatory, financing, and long-term business risks. The issue is particularly relevant to the energy sector, which plays a central role in economic activity while also operating in carbon-intensive industries. As regulatory expectations and investor attention to climate-related risks increase, energy companies face growing pressure to explain their emissions, energy use, reduction targets, and accountability mechanisms through annual and sustainability reports.

Carbon emission disclosure provides information on the amount and sources of emissions, climate-related risks and opportunities, energy consumption, emission-reduction initiatives, costs, and managerial responsibility. The disclosure level, however, remains uneven across Indonesian energy companies. In the present sample, the average disclosure index increased from 0.5104 in 2022 to 0.5763 in 2023 and 0.6337 in 2024, whereas average Tobin's Q declined from 1.4533 in 2022 to 1.2480 in 2023 before recovering to 1.3891 in 2024. This

nonparallel movement suggests that market valuation is influenced by both disclosure and broader firm- and year-specific conditions.

Agency theory explains why carbon information may affect firm value. Managers possess more detailed information than shareholders about emissions, climate risks, required investment, potential environmental liabilities, and the economic consequences of carbon policies. This information asymmetry can increase monitoring costs and allow managers to selectively disclose favorable information. More complete carbon disclosure can reduce that asymmetry by giving shareholders a basis for evaluating managerial decisions and the company's ability to manage carbon-related risks (Jensen & Meckling, 1976).

Prior empirical findings remain inconsistent. Positive effects have been reported by Rusmana and Purnaman (2020), Hardiyansah et al. (2021), Putri and Agustin (2023), and Trimuliani and Febrianto (2023). In contrast, Anggita et al. (2022) and Wijaya and Khairani (2024) found no significant effect, Mahmudah et al. (2023) reported a negative but insignificant association, and Ericho and Amin (2024) found a negative significant effect. Kurnia et al. (2021) also showed that the relationship differed between Indonesian and Australian firms. These mixed results indicate that carbon disclosure does not always have the same informational value across institutional settings, sectors, and disclosure qualities.

Independent commissioners are expected to reduce agency conflicts by monitoring management and improving the reliability of corporate reporting. In the carbon context, effective independent commissioners should discourage selective disclosure and greenwashing, require more complete information, and strengthen the credibility of sustainability reports. Nevertheless, the formal proportion of independent commissioners may not reflect their environmental expertise, involvement, access to information, or substantive independence. Therefore, whether they strengthen the valuation effect of carbon disclosure remains an empirical question.

This study examines energy companies listed on the Indonesia Stock Exchange during 2022-2024. It contributes by applying agency theory as the sole theoretical framework, using a firm-size control and year effects, applying firm-clustered standard errors, and supplementing regression coefficients with predictive margins and marginal-effect analysis. The first hypothesis predicts that carbon emission disclosure positively affects firm value. The second predicts that independent commissioners strengthen the positive effect of carbon emission disclosure on firm value.

METHOD

Research Design

This study uses a quantitative descriptive design. The quantitative approach is applied because all variables are expressed numerically and analyzed statistically, while the descriptive component summarizes the minimum, maximum, mean, median, standard deviation, and annual development of carbon emission disclosure, independent commissioners, firm size, and firm value. The study also has a hypothesis-testing purpose because it evaluates the direct effect of carbon disclosure and the moderating role of independent commissioners using panel-data regression and Moderated Regression Analysis (MRA). The unit of analysis is the firm-year, and the study is nonexperimental because no variable is manipulated.

Population, Sample, and Outlier Treatment

The population comprises energy sector companies listed on the Indonesia Stock Exchange. Purposive sampling was used, requiring companies to be classified in the energy sector and to publish complete audited financial statements, annual reports, and/or sustainability reports for 2022-2024. The initial sample consisted of 61 companies observed for three years, producing 183 firm-year observations.

Table 1. Research Sample Determination

No.	Criteria	Number
1	Identified energy sector companies	91
2	Less: incomplete annual and/or sustainability reports for 2022-2024	(30)
3	Sample companies before outlier treatment	61
4	Observation period	3 years
5	Initial firm-year observations	183
6	Less: Tobin's Q observations outside mean ± 3 standard deviations	(6)
7	Final observations used in regression	177
8	Effective companies in final regression	59

Source: Processed by authors, 2026

Outlier screening focused on Tobin's Q because this market-based ratio can become extreme when market capitalization is disproportionately high relative to total assets. Observations outside the initial-sample mean ± 3 standard deviations were classified as extreme. This conservative rule identified six firm-year observations, consisting of three yearly observations each for Bayan Resources Tbk. and Transcoal Pacific Tbk. The observations were excluded before hypothesis testing to prevent a small number of extreme market valuations from exerting disproportionate influence on the estimated coefficients. The same rule was applied consistently to all observations. The final dataset contained 177 observations from 59 companies. Oprean-Stan et al. (2020) similarly emphasize that extreme and influential observations can impair regression accuracy in models using Tobin's Q.

Variable Measurement

Firm value is proxied by Tobin's Q because the ratio incorporates market equity value, liabilities, and total assets and therefore captures market valuation more comprehensively than equity-only measures (Brigham & Houston, 2019).

$$\text{Tobin's Q} = (\text{Market Value of Equity} + \text{Total Liabilities}) / \text{Total Assets}$$

Carbon emission disclosure is measured using the 18-item index developed by Choi et al. (2013). Each disclosed item receives a score of 1 and each undisclosed item receives 0. The score is divided by 18, producing an index between 0 and 1. The items cover climate-change risks and opportunities, greenhouse-gas emissions, energy consumption, emission reduction and costs, and carbon-emission accountability.

$$\text{Carbon Disclosure Index} = \text{Number of Disclosed Items} / 18$$

The moderating variable is the proportion of independent commissioners, calculated as the number of independent commissioners divided by the total number of commissioners. Firm

size is included as a control variable and measured as the natural logarithm of total assets (Dang et al., 2018).

$$IBC = \text{Independent Commissioners} / \text{Total Commissioners}$$

$$\text{Size} = \ln(\text{Total Assets})$$

Table 2. Carbon Emission Disclosure Indicators

Category	Items
Climate change: risks and opportunities	CC-1: Climate risks and management actions; CC-2: current and future opportunities, threats, and losses.
Greenhouse-gas emissions	GHG-1: measurement method; GHG-2: external verification; GHG-3: total CO ₂ e; GHG-4: Scope 1, 2, or 3 emissions; GHG-5: emissions by fuel; GHG-6: emissions by facility/division; GHG-7: comparison with prior years.
Energy consumption	EC-1: energy output in kWh or terajoules; EC-2: renewable-energy use; EC-3: energy by category, location, or business unit.
Emission reduction and costs	RC-1: specific reduction initiatives; RC-2: targets and target years; RC-3: reductions and cost savings achieved; RC-4: capital expenditure considering future emission costs.
Carbon-emission accountability	AEC-1: executive body or board committee responsible for climate initiatives; AEC-2: board or executive review of climate progress.

Source: Adapted from Choi, Lee, and Psaros (2013)

Table 3. Variable Operationalization

Variable	Measurement	Scale	Reference
Carbon emission disclosure	Disclosed items / 18	Ratio	Choi et al. (2013)
Independent commissioners	Independent commissioners / total commissioners	Ratio	Bawai & Kusumadewi (2021); Wenhao et al. (2022)
Firm value	Tobin's Q = (market value of equity + liabilities) / assets	Ratio	Putri & Agustin (2023)
Firm size	ln(total assets)	Ratio	Dang et al. (2018)

Source: Processed by authors, 2026

Data Analysis

The analysis combines descriptive statistics, panel-data regression, and MRA. The Chow, Hausman, and Lagrange Multiplier tests are used to select among the common-effects, fixed-effects, and random-effects specifications. Year dummy variables control for common conditions in 2023 and 2024, with 2022 as the reference year. The main and moderation models are specified as follows:

$$\text{Tobin}Q_{it} = \alpha + \beta_1 \text{CDP}_{it} + \beta_2 \text{Size}_{it} + \delta_1 D2023 + \delta_2 D2024 + u_i + \varepsilon_{it}$$

$$\text{Tobin}Q_{it} = \alpha + \beta_1 \text{CDP_c}_{it} + \beta_2 \text{IBC_c}_{it} + \beta_3 (\text{CDP_c} \times \text{IBC_c})_{it} + \beta_4 \text{Size}_{it} + \delta_1 D2023 + \delta_2 D2024 + u_i + \varepsilon_{it}$$

CDP and IBC are mean-centered before the interaction term is formed to improve interpretation and reduce nonessential multicollinearity (Aiken & West, 1991). Diagnostic tests cover residual normality, multicollinearity, heteroskedasticity, and autocorrelation. Because heteroskedasticity and within-firm serial correlation are detected, final inference is based on

random-effects estimates with standard errors clustered at the firm level (Liang & Zeger, 1986; Petersen, 2009; Cameron & Miller, 2015). Predictive margins compare adjusted Tobin's Q at low (P25), mean, and high (P75) disclosure levels. Marginal effects are also estimated at low, mean, and high proportions of independent commissioners.

RESULTS AND DISCUSSION

Descriptive Statistics

Table 4. Descriptive Statistics

Variable	N	Maximum	Minimum	Median	Mean	Std. Dev.
CDP	177	1.0000	0.0556	0.6111	0.5734	0.2007
Tobin's Q	177	4.3086	0.2638	1.0440	1.3635	0.7704
IBC	177	1.0000	0.2500	0.4000	0.4450	0.1299
Size	177	32.7578	25.6356	28.9618	29.0610	1.7493

Source: Processed by authors, 2026

The mean CDP score of 0.5734 indicates that firms disclosed, on average, 57.34% of the 18 carbon items. The median of 0.6111 exceeds the mean, showing that several firms with very low disclosure pull the average downward. Tobin's Q has a mean of 1.3635 and a median of 1.0440, indicating a right-skewed distribution and that the average firm is valued above book value. The mean IBC proportion of 0.4450 suggests that independent commissioners represent approximately 44.50% of the board, although the measure captures formal composition rather than monitoring quality. Energy firms are generally large and capital intensive, as indicated by the mean Size of 29.0610.

Panel-Data Model Selection and Diagnostics

Table 5. Panel-Data Model Selection

Test	Statistic	Probability	Decision
Chow test	$F(58,114) = 5.29$	0.0000	Fixed effects preferred to common effects
Hausman test	$\chi^2 = 3.48$	0.1755	Random effects preferred to fixed effects
Lagrange Multiplier	$\text{chibar}^2 = 59.36$	0.0000	Random effects preferred to common effects

Source: Processed by authors, 2026

The Chow test rejects the common-effects model, the Hausman test does not reject the random-effects estimator, and the Lagrange Multiplier test confirms that random effects are superior to common effects. Accordingly, the random-effects model is used for the final estimations.

Table 6. Diagnostic Test Summary

Diagnostic	Result	Conclusion
Normality	Kolmogorov-Smirnov D = 0.1573; p = 0.0000	Residuals are not normally distributed
Multicollinearity	Mean VIF = 1.21	No material multicollinearity
Heteroskedasticity	Glejser: CDP p = 0.025; Size p = 0.003	Heteroskedasticity detected
Autocorrelation	Wooldridge F(1,58) = 7.282; p = 0.0091	First-order autocorrelation detected

Source: Processed by authors, 2026

The model does not exhibit problematic multicollinearity, but residual nonnormality, heteroskedasticity, and autocorrelation are present. These findings do not alter the model-selection decision; rather, they justify using firm-clustered standard errors so that inference remains robust to unequal variances and within-firm error dependence.

Main Model and Predictive Margins

Table 7. Main Random-Effects Model with Firm-Clustered Standard Errors

Variable	Coefficient	Std. Error	z	p-value
CDP	0.6192	0.2740	2.26	0.024*
Size	-0.0764	0.0470	-1.63	0.104
Dummy 2023	-0.2422	0.0724	-3.35	0.001**
Dummy 2024	-0.1325	0.1121	-1.18	0.237
Constant	3.3547	1.4272	2.35	0.019*

*Note: Wald $\chi^2(4) = 22.13$; Prob > $\chi^2 = 0.0002$; overall $R^2 = 0.0840$. * $p < 0.05$; ** $p < 0.01$.*

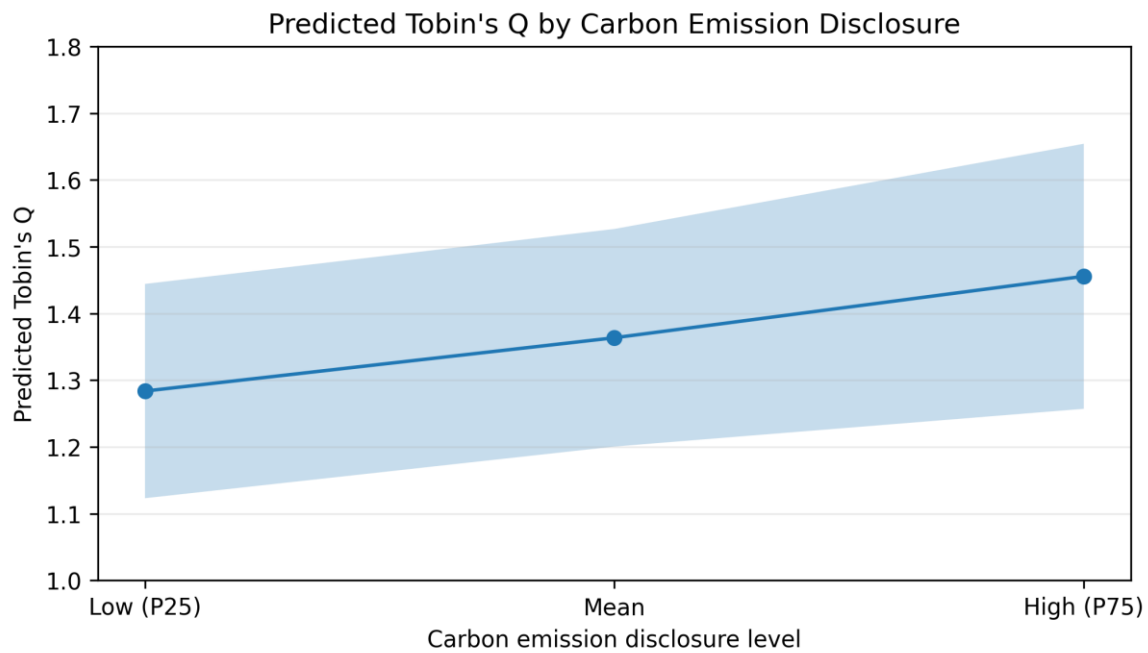
Source: Processed by authors, 2026

The main model is jointly significant. Carbon emission disclosure has a positive coefficient of 0.6192 and a p-value of 0.024, supporting H1. Firm size is negative but insignificant. Firm value in 2023 is significantly below the 2022 reference year, whereas the 2024 difference is not significant. The overall R^2 of 0.0840 indicates that the model explains 8.40% of firm-value variation, which is reasonable given that market valuation is also affected by profitability, leverage, growth prospects, commodity prices, risk, and macroeconomic conditions.

Table 8. Predictive Margins of Tobin's Q at Different Disclosure Levels

Disclosure level	CDP value	Predicted Tobin's Q	Std. Error	95% Confidence Interval
Low (P25)	0.4444	1.2836	0.0819	1.1231-1.4441
Mean	0.5734	1.3635	0.0832	1.2005-1.5265
High (P75)	0.7222	1.4556	0.1013	1.2570-1.6542

Source: Processed by authors, 2026

Figure 1. Predicted Tobin's Q by Carbon Emission Disclosure

Predictive margins provide an economically interpretable comparison. At the 25th percentile of disclosure, corresponding to approximately 8 of 18 disclosed items, predicted Tobin's Q is 1.2836. At the 75th percentile, corresponding to approximately 13 items, predicted Tobin's Q rises to 1.4556. The high-low difference is 0.1720, with $z = 2.26$, $p = 0.024$, and a 95% confidence interval of 0.0228-0.3212. Thus, adjusted firm value at high disclosure is approximately 13.40% higher than at low disclosure. These are model-adjusted predictions rather than raw subgroup means.

Moderation Model and Marginal Effects

Table 9. Moderation Random-Effects Model with Firm-Clustered Standard Errors

Variable	Coefficient	Std. Error	z	p-value
CDP_c	0.6350	0.2946	2.16	0.031*
IBC_c	-0.8575	0.4920	-1.74	0.081
CDP_c $\times$ IBC_c	1.3441	2.2455	0.60	0.549
Size	-0.0608	0.0521	-1.17	0.244
Dummy 2023	-0.2283	0.0699	-3.26	0.001**
Dummy 2024	-0.1255	0.1093	-1.15	0.251
Constant	3.2437	1.5414	2.10	0.035*

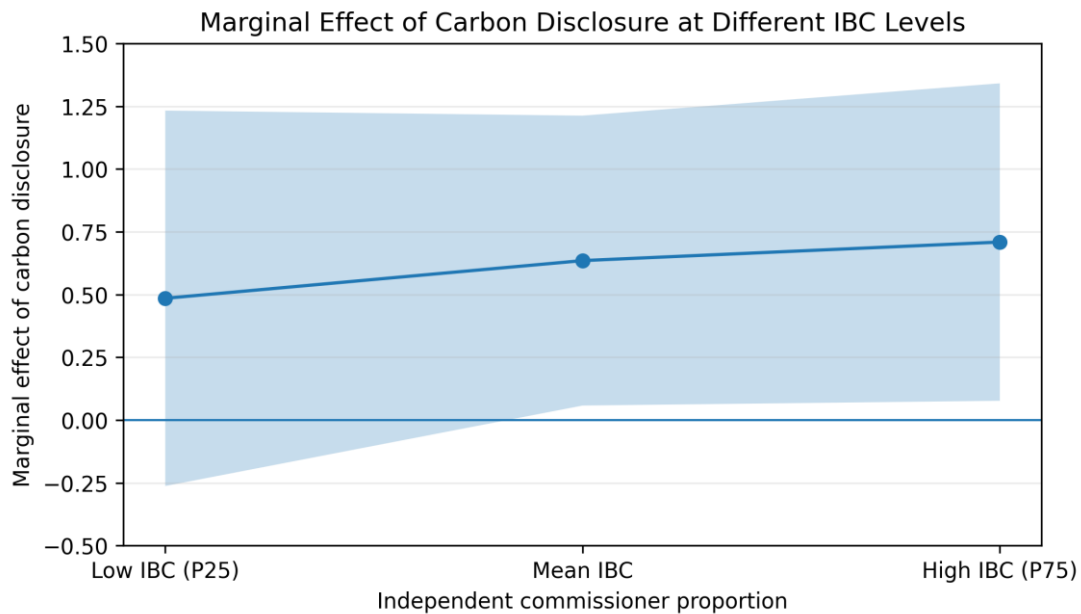
Note: Wald $\chi^2(6) = 25.63$; Prob $> \chi^2 = 0.0003$; overall $R^2 = 0.0784$. * $p < 0.05$; ** $p < 0.01$.
Source: Processed by authors, 2026

Carbon disclosure remains positive and significant when IBC and the interaction term are included. The direct IBC coefficient is not significant at 5%. Most importantly, the CDP_c $\times$ IBC_c interaction is positive but insignificant ($p = 0.549$), so H2 is not supported. The addition of the moderator does not improve explanatory power, as overall R^2 declines slightly to 0.0784.

Table 10. Marginal Effect of Carbon Disclosure at Different IBC Levels

IBC level	Marginal effect of CDP	Std. Error	p-value	95% Confidence Interval
Low (P25)	0.4849	0.3815	0.204	-0.2628-1.2326
Mean	0.6350	0.2946	0.031	0.0577-1.2123
High (P75)	0.7089	0.3225	0.028	0.0767-1.3411

Source: Processed by authors, 2026

Figure 2. Marginal Effect of Carbon Disclosure at Different IBC Levels

The marginal-effect estimates increase from 0.4849 at low IBC to 0.6350 at the mean and 0.7089 at high IBC. The effect is not significant at low IBC but is significant at the mean and high levels. Nevertheless, differences in significance across conditional estimates do not themselves establish moderation. The formal test remains the interaction coefficient, which is insignificant. Figure 2 therefore shows only a descriptive upward tendency, not statistically proven moderation.

Discussion: Carbon Emission Disclosure and Firm Value

The positive and significant disclosure coefficient is consistent with agency theory. Managers possess private information about carbon exposure, environmental liabilities, reduction plans, and future investment needs. More complete disclosure gives shareholders additional information for assessing managerial decisions and reduces uncertainty about the company's risk-management capacity. The predictive-margin results strengthen this interpretation because firms at high disclosure have significantly higher adjusted Tobin's Q than firms at low disclosure.

The findings support Rusmana and Purnaman (2020), Hardiyansah et al. (2021), Putri and Agustin (2023), and Trimuliani and Febrianto (2023). However, they differ from Anggita et al. (2022) and Wijaya and Khairani (2024), who found insignificant effects, Mahmudah et al. (2023), who found a negative but insignificant relationship, and Ericho and Amin (2024), who reported a negative significant effect. These differences may reflect variations in sectors,

periods, institutional environments, disclosure credibility, and the extent to which disclosed information actually reduces information asymmetry. In the Indonesian energy-sector sample, the informational benefits of transparency appear to outweigh the possibility that disclosure reveals additional environmental costs or risks.

Discussion: Moderating Role of Independent Commissioners

Agency theory predicts that independent commissioners strengthen monitoring and reporting credibility. Yet the interaction term is not significant. One explanation is that the IBC proportion is relatively stable and may provide insufficient variation to detect moderation. More importantly, formal board composition does not capture environmental expertise, meeting intensity, access to information, willingness to challenge management, or involvement in carbon strategy. Accordingly, independent commissioners may satisfy governance requirements without substantively improving carbon-reporting quality.

The conditional marginal effects suggest that carbon disclosure may be more valuable at higher IBC proportions, but the wide confidence intervals and insignificant interaction mean that this pattern cannot be generalized as a moderating effect. The result therefore does not reject agency theory as a whole; rather, it indicates that headcount-based board independence is an incomplete proxy for monitoring quality. Future studies should examine board sustainability expertise, dedicated ESG committees, audit quality, institutional ownership, and external assurance of sustainability information.

CONCLUSION

This quantitative descriptive study analyzed 177 firm-year observations from 59 Indonesian energy companies during 2022-2024. Carbon disclosure was measured using an 18-item index, firm value using Tobin's Q, independent commissioners using their board proportion, and firm size using the natural logarithm of total assets. Random-effects panel regression with firm-clustered standard errors was selected after model-selection and diagnostic testing. Carbon emission disclosure positively and significantly affects firm value ($\beta = 0.6192$; $p = 0.024$). Predictive margins show an increase in adjusted Tobin's Q from 1.2836 at low disclosure to 1.4556 at high disclosure, with a significant difference of 0.1720. These results support the agency-theory argument that disclosure can reduce information asymmetry and monitoring costs.

Independent commissioners do not significantly moderate the relationship ($\beta = 1.3441$; $p = 0.549$). Although marginal effects rise across low, mean, and high IBC levels, the interaction remains statistically insignificant. The formal proportion of independent commissioners therefore does not adequately represent substantive monitoring effectiveness. Firm size is also insignificant. The study is limited by a three-year period, a relatively low R^2 , the sensitivity of Tobin's Q to market extremes, and the use of board proportion rather than board quality. Energy companies should improve the depth, consistency, measurability, and verifiability of carbon disclosures. Governance reforms should emphasize sustainability competence and active oversight rather than formal independence alone. Future research should extend the observation period, compare sectors, include additional financial controls, and use richer governance measures.

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