

Research Article

The Effect of Carbon Risk on Firm Value: An Empirical Study on Companies Listed on the IDX 2024 Period

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Abstract: Climate change and increasing carbon emissions have raised concerns regarding how investors evaluate firms exposed to carbon-related risks. This study focuses on companies listed on the Indonesia Stock Exchange (IDX) and examines whether Carbon Risk influences Firm Value. Although carbon emissions are often associated with regulatory, financial, and reputational risks, previous studies have reported mixed findings regarding their impact on firm valuation. Therefore, this study aims to analyze the effect of Carbon Risk on Firm Value and investigate whether High Carbon Intensity Industry (HCII) moderates this relationship. Using a quantitative approach, this study employs cross-sectional data from 459 companies listed on the IDX in 2024. Carbon Risk is measured using the natural logarithm of total Scope 1 and Scope 2 carbon emissions, while Firm Value is proxied by Tobin's Q. Multiple Linear Regression Analysis and Moderated Regression Analysis (MRA) are used to test the hypotheses. The results show that Carbon Risk does not have a significant effect on Firm Value. However, the interaction between Carbon Risk and HCII is positive and statistically significant, indicating that industry carbon intensity significantly moderates the relationship between Carbon Risk and Firm Value. These findings suggest that investors may interpret carbon emissions differently across industries, particularly in sectors where high emissions are considered a normal consequence of business operations. Therefore, industry characteristics play an important role in shaping market responses to carbon-related information.

Keywords: Carbon Risk; Corporate Carbon Emissions; Firm Value; Investor Perception; Tobin's Q.

1. Introduction

Climate change has become one of the most significant global challenges, increasing concerns regarding the environmental impact of corporate activities. Carbon emissions, as the primary contributor to greenhouse gases, have attracted growing attention from governments, regulators, investors, and other stakeholders. As environmental issues become increasingly integrated into business and investment decisions, companies are expected to manage and disclose information related to their carbon emissions and climate-related risks. Consequently, carbon-related information has evolved from being solely an environmental concern to becoming an important factor that may influence corporate performance and market valuation (Achakulwisut et al., 2023; Q. Wang, 2023; Y. Wang et al., 2022).

Carbon emissions may expose firms to various risks, commonly referred to as Carbon Risk. These risks arise from potential regulatory changes, carbon taxes, environmental compliance costs, reputational pressures, and the transition toward a low-carbon economy. Such conditions may increase operational uncertainty, affect future cash flows, and raise the cost of capital, ultimately influencing investor perceptions and firm value (Balachandran & Nguyen, 2018; Dewaelheyns et al., 2023). From a signalling perspective, environmental information can serve as an indicator of a firm's future prospects and risk profile. Investors may

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therefore incorporate carbon-related information into their valuation decisions when assessing a company's long-term sustainability and financial performance (Choi & Luo, 2021; Moussa & Elmarzouky, 2024).

Previous studies have extensively examined the relationship between carbon-related information and firm value. Most findings suggest that higher carbon emissions are associated with lower market valuation because investors perceive carbon-intensive firms as being exposed to greater environmental liabilities and future regulatory burdens. Matsumura et al. (2014), Clarkson et al. (2015), Baboukardos (2017), Griffin et al. (2021), and Choi and Luo (2021) reported that carbon emissions negatively affect firm value. However, empirical evidence remains inconclusive. Several studies have documented insignificant or mixed results, indicating that the market response to carbon-related information may vary depending on the research setting, measurement approach, and institutional environment (Apriliani et al., 2024; Askiah et al., 2025).

One possible explanation for these inconsistent findings is that previous studies have largely focused on the direct relationship between carbon-related information and firm value while paying limited attention to industry characteristics. Carbon emissions are not distributed equally across industries. Firms operating in sectors such as energy, mining, transportation, and heavy manufacturing generally produce higher emissions because their business activities are naturally more carbon intensive. As a result, investors may interpret carbon emissions differently across industries. Emissions generated by firms operating in carbon-intensive industries may be viewed as an inherent consequence of business operations rather than a signal of poor environmental performance (Y. Wang et al., 2022). Therefore, industry carbon intensity may influence how investors evaluate carbon-related information and its implications for firm value.

The Indonesian context provides an interesting setting to examine this issue. As an emerging economy, Indonesia continues to strengthen its commitment to environmental sustainability while maintaining economic growth. At the same time, awareness of environmental, social, and governance (ESG) issues among investors has gradually increased. Nevertheless, compared to developed markets, the integration of carbon-related information into investment decisions in Indonesia may still be developing (Askiah et al., 2025). Consequently, the extent to which Carbon Risk influences Firm Value, particularly across industries with different carbon intensity levels, remains an important empirical question.

Accordingly, this study aims to examine the effect of Carbon Risk on Firm Value and investigate whether High Carbon Intensity Industry (HCII) moderates the relationship. Carbon Risk is measured using the natural logarithm of total Scope 1 and Scope 2 carbon emissions, while Firm Value is measured using Tobin's Q. This study contributes to the literature by providing evidence from Indonesian listed companies, incorporating actual carbon emission data as a proxy for Carbon Risk, and examining the moderating role of HCII in the relationship between Carbon Risk and Firm Value.

2. Literature Review

Agency Theory

Agency Theory explains the relationship between principals (shareholders) and agents (management) within a company. (Jensen & Meckling, 1976) argue that managers often possess more information regarding corporate activities and risks than shareholders, creating information asymmetry. To reduce this asymmetry, firms are encouraged to disclose relevant information that enables investors to evaluate company performance and future prospects. Environmental information, including carbon emissions and climate-related risks, represents one form of disclosure that may help investors assess potential environmental liabilities and future financial consequences. Consequently, carbon-related information can influence investment decisions and market valuation because it provides additional insight into a firm's risk profile and long-term sustainability.

Legitimacy Theory

Legitimacy Theory suggests that organizations continuously seek to ensure that their operations are aligned with societal values, norms, and expectations (Suchman, 1995). Corporate legitimacy is essential because it allows firms to maintain stakeholder support and secure access to resources necessary for long-term survival. Growing public awareness regarding climate change has increased expectations for companies to manage and disclose their environmental impacts. Firms that generate substantial carbon emissions may face greater scrutiny from regulators, investors, and society, potentially threatening their legitimacy. As a result, companies often adopt environmental initiatives and sustainability practices to demonstrate their commitment to responsible business conduct and maintain stakeholder confidence.

Natural Resource-Based View

The Natural Resource-Based View (NRBV), proposed by (Hart, 1995), extends the traditional Resource-Based View by emphasizing environmental capabilities as a source of competitive advantage. According to NRBV, firms can enhance long-term performance through effective environmental management, resource efficiency, pollution prevention, and sustainability-oriented innovation. Environmental challenges should not only be viewed as costs but also as opportunities to strengthen competitiveness and create firm value. In the context of carbon emissions, companies that successfully manage carbon-related risks may improve operational efficiency, strengthen stakeholder trust, and enhance long-term business sustainability. Therefore, carbon management may influence firm value through its impact on strategic resources and competitive positioning.

Carbon Risk

Carbon Risk refers to the potential financial and economic consequences arising from a firm's exposure to carbon emissions and climate-related regulations. Companies with higher emission levels may face greater environmental compliance costs, carbon taxes, reputational pressures, and transition risks associated with the shift toward a low-carbon economy. These risks can increase operational uncertainty, affect future profitability, and influence investor perceptions regarding firm performance (Balachandran & Nguyen, 2018; Dewaelheyns et al., 2023).

Previous studies commonly measure Carbon Risk using greenhouse gas emissions disclosed by companies, particularly Scope 1 and Scope 2 emissions based on the Greenhouse Gas Protocol framework. Scope 1 emissions represent direct emissions generated from company-owned or controlled sources, while Scope 2 emissions represent indirect emissions resulting from purchased electricity and energy consumption. These measures are frequently used because they directly reflect a firm's operational environmental impact and are generally disclosed more consistently than Scope 3 emissions. Following prior literature, this study measures Carbon Risk using the natural logarithm of total Scope 1 and Scope 2 emissions disclosed by firms (Choi & Luo, 2021; Perdichizzi et al., 2024; Sun et al., 2022).

Firm Value

Firm Value reflects investors' overall assessment of a company's current performance, future prospects, and risk exposure. Higher firm value generally indicates stronger investor confidence regarding a firm's ability to generate future cash flows and sustain long-term growth. Consequently, firm value is frequently used as an important indicator for examining how financial and non-financial factors influence market valuation (Wardana et al., 2025).

Several measures have been used to assess firm value, including Price-to-Book Value (PBV), Market-to-Book Ratio, and Tobin's Q. Among these measures, Tobin's Q is widely employed in accounting and finance research because it incorporates market expectations regarding future performance and risk. Tobin's Q captures the relationship between the market value of a firm and the value of its assets, allowing researchers to evaluate how investors respond to various forms of corporate information (Chung & Pruitt, 1994). Because environmental risks may affect investor expectations regarding future costs and profitability, Tobin's Q is considered an appropriate proxy for examining the impact of Carbon Risk on Firm Value.

High Carbon Intensity Industry

High Carbon Intensity Industry (HCII) refers to industries characterized by relatively high levels of carbon emissions and energy consumption resulting from their operational activities. These industries typically rely on resource-intensive production processes, substantial fossil fuel usage, and activities that directly generate greenhouse gas emissions. Examples include the energy, mining, transportation, and heavy manufacturing sectors (Han et al., 2021).

Industry characteristics may influence how investors interpret carbon-related information. Investors generally evaluate firms relative to industry norms and operational realities rather than applying identical standards across all sectors. Consequently, higher emissions may be perceived differently depending on the industry's carbon intensity. In carbon-intensive industries, emissions may be viewed as a normal consequence of business operations (Perdichizzi et al., 2024), whereas similar emission levels may be interpreted more negatively in less carbon-intensive industries. Therefore, HCII may serve as an important contextual factor affecting the relationship between Carbon Risk and Firm Value. In this study, HCII is employed as a moderating variable and measured using a dummy classification. Firms operating in subsectors classified as high carbon intensity are assigned a value of 1, while firms operating in other subsectors are assigned a value of 0.

Hypothesis Development

Carbon emissions may create future environmental liabilities and increase uncertainty regarding corporate performance. Firms with higher carbon emissions are generally more exposed to regulatory changes, carbon pricing mechanisms, environmental compliance costs, and reputational risks. These conditions may reduce investor confidence and increase the perceived risk associated with future cash flows. Consistent with Agency Theory and Legitimacy Theory, investors may incorporate carbon-related risks into their valuation decisions when assessing a firm's future prospects. Empirical evidence from Matsumura et al. (2014), Choi & Luo (2021), and Griffin et al. (2021) indicates that firms with higher carbon emissions tend to experience lower market valuation.

H1: There is a negative effect relationship between carbon risk and firm value.

The effect of Carbon Risk on Firm Value may vary depending on industry characteristics. Firms operating in high carbon intensity industries naturally generate higher emissions due to the nature of their business activities. Consequently, investors may perceive carbon emissions in these industries differently from emissions generated by firms operating in less carbon-intensive sectors. Consistent with the Natural Resource-Based View, industry context may influence how environmental information is interpreted and incorporated into market valuation (Ott & Schiemann, 2023). Therefore, High Carbon Intensity Industry is expected to moderate the relationship between Carbon Risk and Firm Value.

H2: High Carbon Intensity Industry moderates the relationship between Carbon Risk and Firm Value.

3. Research Method

Population and Sample

The population of this study consists of all companies listed on the Indonesia Stock Exchange (IDX) in 2024. A purposive sampling method is employed to select firms that disclose carbon emission information and provide complete financial data required for the research variables.

The final sample comprises 459 companies. Data are obtained from annual reports, sustainability reports, and financial statements published by the sampled firms.

Variables and Measurement

This study examines one dependent variable (Firm Value), one independent variable (Carbon Risk), one moderating variable (High Carbon Intensity Industry), and two control variables (Leverage and Return on Assets). Firm Value is measured using Tobin's Q, calculated as $(\text{Market Value of Equity} + \text{Total Liabilities}) / \text{Total Assets}$ (Chung & Pruitt, 1994). Carbon Risk is measured using the natural logarithm of total Scope 1 and Scope 2 carbon emissions disclosed by firms, following prior studies that use actual carbon emissions as a proxy for carbon-related risk exposure (Choi & Luo, 2021; Dewaelheyns et al., 2023). High Carbon Intensity Industry (HCII) is measured using a dummy variable, where firms operating in high carbon intensity subsectors are assigned a value of 1 and firms operating in non-high carbon intensity subsectors are assigned a value of 0 (Han et al., 2021). The control variables include Leverage, measured as Total Liabilities divided by Total Assets, and Return on Assets (ROA), measured as Net Income divided by Total Assets (Qowiyyul Adib et al., 2024).

4. Results and Discussion

Table 1. Descriptive Statistical Analysis.

	TOBINSQ	CRISK	LEV	ROA	CRISK*HCII
(N) Valid	459	459	459	459	459
(N) Missing	0	0	0	0	0
Mean	2.3688	9.4447	1.4815	1.9798	0.9504
Median	0.8400	9.7300	0.7800	2.590	0.0000
Std. Deviation	7.36003	3.41142	3.14851	18.82999	5.49857
Range	118.04	22.12	51.64	340.12	111.93
Minimum	-6.79	-3.96	-10.39	-258.17	-0.68
Maximum	111.25	18.16	41.25	81.95	111.25

Table 2. Frequency Distribution of Human Capital Intensity (HCI).

		HCII			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	248	54.0	54.0	54.0
	1	211	46.0	46.0	100.0
	Total	459	100.0	100.0	

The descriptive statistics indicate substantial variation across the research variables. Firm Value ranges from -6.790 to 111.250, with a mean of 2.369 and a standard deviation of 7.360, suggesting considerable differences in market valuation among firms. Carbon Risk ranges from -3.960 to 18.160, with a mean of 9.445 and a standard deviation of 3.411, indicating varying levels of carbon emission exposure across companies. Leverage ranges from -10.390 to 41.250, with an average of 1.482 and a standard deviation of 3.149, reflecting differences in capital structure among sample firms. Return on Assets (ROA) ranges from -258.170 to 81.950, with a mean of 1.980 and a standard deviation of 18.830, indicating substantial variation in profitability. The interaction variable between Carbon Risk and High Carbon Intensity Industry (CRISK×HCII) ranges from -0.680 to 111.250, with a mean of 0.950 and a standard deviation of 5.499. Regarding industry classification, 248 firms (54.0%) are categorized as non-High Carbon Intensity Industry (non-HCII), while 211 firms (46.0%) are classified as HCII, providing a relatively balanced distribution for examining the moderating effect of industry carbon intensity.

Table 3. Coefficient of Determination Test (Without Moderation).

Indicator	Value
R	0.188
R Square (R ²)	0.035
Adjusted R Square	0.029
Std. Error of the Estimate	7.25318

The regression model produces an R value of 0.188 and an R² of 0.035, indicating that the independent and control variables explain 3.5% of the variation in Firm Value. The adjusted R² of 0.029 suggests relatively low explanatory power, implying that Firm Value is influenced by other factors not included in the model. The standard error of the estimate is 7.253.

Table 4. Coefficient of Determination Test (With Moderation).

Indicator	Value
R	0.746
R Square (R^2)	0.556
Adjusted R Square	0.551
Std. Error of the Estimate	4.9322

The moderated model reports an R^2 of 0.556 (Adjusted $R^2 = 0.551$), indicating substantial explanatory power. The increase in R^2 and reduction in the standard error of estimate to 4.932 suggest that incorporating HCII improves the model's ability to explain variations in Firm Value.

Table 5. F-Test (Without Moderation).

Indicator	Value
F Statistic	5.531
Significance	0.001

The F-statistic of 5.531 with a significance value of 0.001 indicates that the regression model is statistically significant. This result suggests that the independent and control variables jointly explain variations in Firm Value.

Table 6. F-Test (With Moderation).

Indicator	Value
F Statistic	113.373
Significance	0.000

The moderated regression model is statistically significant F-statistic of 113.373 and significance value of <0.000 , indicating that the independent, moderating, interaction, and control variables collectively explain variations in Firm Value.

Table 7. T-Test (Without Moderation).

Variables	Coefficient (B)	t-Statistic	Sig.
CRISK	-0.022	-0.217	0.828
LEV	0.428	3.971	0.000
ROA	0.015	0.852	0.395

Carbon Risk exhibits a negative coefficient of -0.022 but is not statistically significant (Sig. = 0.828), indicating that Carbon Risk does not affect Firm Value. Leverage has a positive and significant coefficient of 0.428 (Sig. = 0.000), while Return on Assets has a positive but insignificant coefficient of 0.015 (Sig. = 0.395).

Table 8. T-Test (With Moderation).

Variables	Coefficient	t-Statistic	Sig.
CRISK	-0.107	-1.512	0.131
LEV	0.265	3.582	0.000
ROA	0.013	1.034	0.302
HCII	-2.291	-4.64	0.000
CRISK*HCII	0.989	23.031	0.000

Carbon Risk exhibits a negative coefficient of -0.107 but is not statistically significant (Sig. = 0.131), indicating that Carbon Risk does not affect Firm Value. Leverage has a positive and significant coefficient of 0.265 (Sig. = 0.000), while Return on Assets has a positive but insignificant coefficient of 0.013 (Sig. = 0.302). High Carbon Intensity Industry exhibits a negative and significant coefficient of -2.291 (Sig. = 0.000), suggesting that firms operating in carbon-intensive industries tend to have lower Firm Value. Meanwhile, the interaction term between Carbon Risk and HCII has a positive and significant coefficient of 0.989 (Sig. =

0.000), indicating that HCII significantly moderates the relationship between Carbon Risk and Firm Value.

5. Discussion

The Effect of Carbon Risk on Firm Value

The results indicate that Carbon Risk does not significantly affect Firm Value. Although the coefficient is negative in both regression models, the relationship remains statistically insignificant. This finding suggests that investors do not directly incorporate corporate carbon emissions into firm valuation. One possible explanation is that investors continue to prioritize traditional financial indicators, such as profitability, growth opportunities, and capital structure, when evaluating firms. In addition, the Indonesian capital market may still be in a transitional stage regarding the integration of environmental considerations into investment decisions. Consequently, firms with higher carbon emissions are not necessarily penalized through lower market valuations. This finding is consistent with Askiah et al. (2025), who argue that carbon-related information may not immediately influence firm value when investors perceive environmental risks and regulatory pressures as relatively limited.

The Moderating Role of High Carbon Intensity Industry

The results show that High Carbon Intensity Industry significantly moderates the relationship between Carbon Risk and Firm Value. The positive interaction coefficient indicates that the negative effect of Carbon Risk becomes weaker among firms operating in carbon-intensive industries. One possible explanation is that investors recognize higher emissions as an inherent characteristic of industries such as energy, mining, transportation, and heavy manufacturing. Since these industries naturally rely on emission-intensive production processes, higher carbon emissions may be viewed as a normal outcome of business operations rather than solely as an indicator of environmental risk. As a result, the negative market response associated with carbon emissions tends to be reduced. This finding supports the argument that the valuation effect of carbon-related information depends on industry characteristics and the context in which emissions occur (Ott & Schiemann, 2023). Investors tend to evaluate environmental information relative to industry-specific expectations rather than applying the same benchmark across all firms. Therefore, the impact of Carbon Risk on Firm Value varies across industries, with the negative effect becoming weaker among firms operating in high carbon intensity sectors. These findings indicate that industry carbon intensity serves as an important contextual factor in shaping investor perceptions of carbon-related information.

6. Conclusions

The analysis shows that Carbon Risk does not significantly affect Firm Value, indicating that corporate carbon emissions are not directly reflected in market valuation. Although the relationship is negative, investors do not appear to penalize firms with higher emissions, suggesting that environmental considerations may not yet play a dominant role in investment decisions within the Indonesian capital market.

High Carbon Intensity Industry significantly moderates the relationship between Carbon Risk and Firm Value. The positive interaction effect indicates that the negative impact of Carbon Risk becomes weaker among firms operating in carbon-intensive industries. This finding suggests that investors tend to interpret carbon emissions within the context of industry characteristics, where higher emissions are often viewed as an inherent consequence of business operations rather than solely as an environmental liability.

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