THE IMPACT OF CARBON RISK ON STOCK RETURNS AND VOLATILITY: THE MODERATING ROLE OF ENVIRONMENTAL INNOVATION

Isnaini Nuzula Agustin[1], Darwin[2], Yandi Suprapto[3]
[1,2,3]Universitas Internasional Batam, Indonesia
Email: isnaini.nuzula@uib.ac.id

Abstract

The growing carbon risks Indonesian businesses confront as the nation moves toward a low carbon economy are the driving force behind this study. Increased regulatory expenses, reputational hazards, and market uncertainty are some of the ways that carbon concerns can impact stock performance. The purpose of this study is to examine how carbon hazards affect stock returns and stock volatility and to determine whether environmental innovation plays a moderating function. Using secondary data from 76 businesses listed on the IDX between 2016 and 2024 a total 474 observations, the study takes a quantitative approach. Panel data regression was used to analyse the data, and control variables included ROA, ROE, company size, market capitalisation, and leverage. The findings show that stock returns and stock volatility are positively and significantly impacted by carbon risk. Additionally, it was discovered that while environmental innovation had moderate effect on stock volatility, it also weaken the impact of carbon risk on stock returns. These results imply that one important tactic for reducing the effects of carbon risk and boosting investor confidence is environmental innovation. In order to assist carbon risk management and the sustainability of Indonesia's capital market, this study has implications for businesses, investors, and regulators.

Keywords: *Carbon Risk, Stock Performance, Environment Innovation , Stock Return, Stock Volatility.*

A. INTRODUCTION

Indonesia is a growing country that relies largely on enterprises that use fossil fuels. Because of this, the country's expanding carbon emissions are a substantial carbon risk to the stock performance of publicly traded corporations. Indonesia is committed to the Paris Agreement, which means that it has to cut down on emissions through rules like Presidential Regulation No. 98/2021 and Presidential Regulation No. 110/2025 on the economic value of carbon. These include carbon taxes and carbon trading on the IDX Carbon platform, which began in 2023. In this case, there is a "high carbon, high cost, high risk" dynamic, where large emissions show that operations aren't going well and boost regulatory expenses. Then, investors utilize the efficient market hypothesis to figure out what bad news about stock prices means (Sidharta & Kim, 2024; Yaqin et al., 2025).

Carbon risk makes stocks less profitable in developing countries like Indonesia because investors don't want to buy stocks of companies that emit a lot of carbon since they might face fines and the market doesn't like them. Research on Chinese A share companies shows that carbon risk lowers stock returns by lowering institutional ownership. This "high carbon, high cost, high risk" phenomenon is corroborated by empirical studies in Asia Pacific, indicating that income inequality and environmental degradation, including carbon emissions, impede the low carbon transition, thus elevating carbon risk for companies in Indonesia in accordance with the Paris Agreement and IDX Carbon (Agustin et al., 2026). In Indonesia, ESG performance has a big effect on market returns. For example, strong environmental ratings can make stock prices less volatile by encouraging sustainable innovation (Agustin et al. 2024). This is

important for Indonesia's growing carbon market. Furthermore, an analysis of carbon emissions in Indonesia reveals a direct relationship between fluctuations in emissions and stock market volatility, highlighting the imperative to mitigate this risk for stable returns (Ren et al., 2023).

Carbon risk makes stocks less stable, especially for businesses that emit a lot of emissions. This is because stock values go up and down when people don't know how the low carbon transition will go. Research in the Chinese market showed that high carbon emissions are linked to unusual price changes and a higher chance of price drops. These impacts are made worse by strict rules, as those put in place in Indonesia after the Paris Agreement. In Southeast Asia, things tend to be less volatile when ESG scores are high, such for carbon management. This demonstrates the vulnerability of the Indonesian stock market to this issue (Asih et al., 2024).

The environment innovation is a moderating factor that lowers the negative effects of carbon risk on stock performance by encouraging technology breakthroughs that lower emissions and enhance how investors see things. Green technology help make the market and interest rates less volatile. This is significant for Indonesian businesses who are switching to cleaner energy sources. ESG research in Indonesia confirms that higher environment ratings reduce stock volatility, hence strengthening this moderating effect on market returns and volatility (Rizki et al., 2023).

This study offers a novel contribution through an empirical examination of the moderating role of the environment innovation in mediating the relationship between carbon risk dan stock performance among IDX listed companies during the 2016-2024 period, thereby filling a gap in the literature on emerging markets by focusing on stock volatility resulting from the IDX Carbon transition. Its primary contribution lies in the evidence that the innovation score can reduce investor sensitivity to carbon emissions, using a panel data regression model that controls for factors such as leverage,market capitalization,and industry,making it relevant for national low carbon policies (Akib et al., 2025; Artika et al., 2025; Rahmasari & Irwansyah, 2024).

Theoretically, this study enriches the resource based view (RBV) and signaling theory with the finding that the environment innovation measured through indicators such as environment R&D spending, green technology patents, and eco innovation output enhances a company’s legitimacy in the eyes of the stakeholders and reduces stock volatility amid Paris Agreement regulations. Practically, the results offer recommendations for IDX regulators and managers to integrate innovation score metrics into sustainability reporting, as well as support Indonesia’s emission reduction targets (Fitriana et al., 2024; Putri & Agustin, 2023; Ramadhan et al., 2025; Zahra, 2026).

B. LITERATURE REVIEW

Research on the relationship between carbon risk, environment innovation, and stock performance is based on several key theories, namely stakeholder theory and the resource based view (RBV). According to stakeholder theory, businesses are answerable to all stakeholders, including the community, the government, and the environment, in addition to shareholders. As environmental, social, and governance (ESG) issues get more attention and stakeholder pressure pushes businesses to manage their environmental impacts more responsibly, this theory has grown more pertinent in today's world.

According to this study, one of the main elements affecting stakeholder perceptions especially those of investors is carbon risk. High carbon emissions can lower a company's attractiveness to investors by raising operational, regulatory, and reputational expenses. According to earlier studies, stock returns are significantly impacted by carbon risk as investors grow more conscious of sustainability and environmental issues (Chen et al., 2025; Wu et al., 2025). Additionally, it has been demonstrated that stakeholder pressure on ESG affects both

market performance and business policy (Chen et al., 2025; Khatib et al., 2023; Wu et al., 2025).

Additionally, engaging in environment innovation and implementing good carbon management methods can boost stakeholder trust and improve the company's reputation in the marketplace. Better long term business performance and stable stock prices result from this. As a result, stakeholder theory offers a solid theoretical framework for elucidating how investors' and other stakeholders' reactions to environment innovation and carbon risk affect stock performance. According to the Resource Based View (RBV), a company's competitive advantage is derived from its own internal resources and competencies that are valued, distinctive, hard to replicate, and difficult to replace. Environment innovation is seen in this study as a strategic resource that can improve market performance and business value.

Investing in environment research and development (R&D), creating eco friendly technologies, and putting in place more effective and sustainable industrial methods are all examples of environment innovation. According to earlier studies, environment innovation significantly affects capital market and company performance (Dussaux et al., 2023; Hajdukiewicz & Pera, 2023; Macchioni et al., 2024). This implies that businesses with the ability to create environmental advances will have a competitive edge that boosts stock performance. Additionally, environment innovation contributes to reducing the adverse effects of carbon risk. Businesses with high levels of environment innovation are typically better able to control carbon emissions, which lowers regulatory risks and boosts operational effectiveness. According to Adu et al. (2023), environment innovation can lessen the detrimental effects of carbon risk while enhancing the connection between environmental performance and business value.

Therefore, RBV clarifies that environment innovation is an internal company strategy for generating value, boosting competitiveness, and bolstering stock performance amid the difficulties of the shift to a low carbon economy, rather than just a reaction to external constraints.

Stock Return and Stock Volatility

The dependent variables in research on carbon risk are typically stock returns, stock volatility, and firm performance more broadly. Stock returns measure the returns investors earn from stock ownership over a specific period. Stock volatility refers to fluctuations or changes in stock prices over a specific period, which is often used as an indicator of investment risk. Meanwhile, firm performance can be explained through financial ratios such as ROA, Tobin’s Q, ROE, and the company’s market value. According to Miah et al. (2021) and Khatib et al. (2023), these variables are measured using stock market data, financial statements, and indices such as ESG. This empirical data is adjusted to account for the characteristics of individual companies and industries to provide a comprehensive picture of the impact of carbon risk and environment innovation on a company’s market and financial performance.

The Impact of Carbon Risk on Stock Returns

Carbon risk refers to risks associated with a company’s carbon emissions that have the potential to cause negative impacts on both the environment and the company’s economic value. Chen et al. (2025) demonstrate that carbon risk has a significant and negative effect on stock returns in the Chinese market. This implies that the higher a company’s carbon risk, the lower the potential returns received by investors. The decline in returns stems not only from negative market sentiment but also from reduced holdings by institutional investors who are more sensitive to environmental risks.

Reshetnikova et al. (2023) in Russia reinforce these findings by highlighting that companies with higher carbon emissions generally have lower stock returns compared to more

environmentally friendly companies. Wu et al. (2025) also confirm that the implementation of carbon management practices improves market perception of a company, thereby reducing risk and increasing returns in the long term. Higher carbon risk tends to lower stock returns due to higher regulatory cost, investor worries, and sustainability pressures,according to further empirical data. Meanwhile Khatib et al., (2023) and Miah et al., (2021) reveal that environment risk reduces business performance and market returns. Bolton and Kacperczyk (2020) demonstrate that investors seek larger risk premiums for carbon intensive firms. Further evidence that increased carbon exposure lower investor confidence in emerging economies is provided by Agustin et al., (2026) and Yaqin et al., (2025) which supporting the negative correlation between carbon risk and stock returns.

H_{1a}: Carbon risk has a significant and negative impact on stock returns

The Impact of Carbon Risk on Stock Volatility

The impact of carbon risk extends beyond returns and significantly influences stock volatility. Chen et al. (2025) found that carbon risk can serve as a predictor of increased risk of future stock price crashes. This means that companies with high carbon risk tend to experience significant stock price fluctuations, which can trigger major uncertainty in the market. This is reinforced by Reshetnikova et al. (2023), who found a relationship between environmental risk and stock volatility among S&P 500 companies in the United States.

Ott and Schiemann (2023), in their study of the U.S. carbon intensive industry, also demonstrated that unexpected carbon emissions negatively impact firm value and increase stock volatility. Therefore, effective carbon risk management is not only crucial for maintaining returns but also for reducing volatility and ensuring the stability of a company's stock value in the capital market. From a modern financial perspective, the concept of carbon risk is also linked to systematic risks in the transition toward a low carbon economy. These risks include regulatory, reputational, and technological risks. Luo et al. (2025) emphasize that carbon risk can affect a company's investment efficiency as well as other economic decisions. Additionally, X. Ren et al. (2023) found that high carbon emissions are correlated with increased market risk and stock volatility, reflecting investor uncertainty regarding future environmental policies.

Thus, it can be concluded that carbon risk has a significant positive impact on stock volatility the higher the carbon risk faced by a company, the higher its stock volatility due to increased market uncertainty, whether in terms of regulation, reputation, or the transition to a low carbon economy (Chen et al., 2025; Ott & Schiemann, 2022; Reshetnikova et al., 2023). Therefore, effective carbon risk management is not only important for maintaining returns but also for reducing volatility and providing stability to a company's stock value in the capital market.

H_{1b}: Carbon risk has a significant and positive effect on stock volatility

The Impact of Environment Innovation on Carbon risk and Stock Return

In order to lower carbon risk and boost stock profits, environment innovation is essential. According to Adu et al. (2023), businesses that have a high degree of environment innovation are typically better equipped to cut carbon emissions, which lowers the carbon risk they face. Additionally, a company's corporate value and investor confidence in its long term commercial prospects are increased when it can effectively manage environment risks through innovation.

S. Ren et al. (2022) discovered that a company's economic and environment performance can be simultaneously enhanced by environmentally friendly technology advances that arise from the implementation of carbon trading schemes. Additionally, Galama and Scholtens (2021) show how innovation improves environment performance, which in turn

improves a company's financial performance and stock returns. Macchioni et al. (2024) corroborate these conclusions, explaining that environment innovation is very valuable to investors since it shows a company's capacity to provide long term competitive advantages. Furthermore, according to Dussaux et al. (2023), businesses that innovate in the environment typically have greater economic value and productivity than less inventive businesses.

Because environment innovation increases corporate value, boosts investor confidence, and improves environment performance, it has a significant positive impact on stock returns and a significant (Adu et al., 2023; Dussaux et al., 2023; Galama & Scholtens, 2021; Macchioni et al., 2024; S. Ren et al., 2022).

H_{2a} : Environment Innovation has a significant negative effect on carbon risk and a significant positive effect on stock return

The Impact of Environment Innovation on Carbon risk and Stock Volatility

Because environment innovation can lower carbon risk and raise investor interest in companies, it also affects stock volatility. Adu et al. (2023) explain that companies actively engaged in environment innovation are better able to control carbon emissions and environmental risks. This finding is supported by S. Ren et al. (2022), who show that green innovation can enhance a company's ability to address transition risks associated with the shift toward a low carbon economy.

Environment innovation can affect stock volatility in addition to lowering carbon risk. Treepongkaruna et al. (2024) demonstrate that environment innovation has a positive relationship with carbon emissions management, while Macchioni et al. (2024) explain that environment innovation constitutes critical information that investors consider when assessing a company's prospects. Dussaux et al. (2023) also state that environment innovation is often followed by changes in business strategy and the development of new technologies that can influence investors' expectations regarding a company's future performance.

Furthermore, research on environmental factors and capital markets indicates that sustainability related information can influence investor behavior and stock price movements (Asih et al., 2024; Zhou & Zhou, 2021)et al., 2024; Zhou & Zhou, 2021). When companies demonstrate higher levels of environment innovation, investors tend to respond more strongly to such information, leading to more active changes in stock prices.

Thus, it can be concluded that environment innovation has a significant negative effect on carbon risk and a significant positive effect on stock volatility because it increases investor attention to a company's prospects and sustainability (Adu et al., 2023; Asih et al., 2024; Dussaux et al., 2023; Macchioni et al., 2024; Majida & Suwarno, 2025; S. Ren et al., 2022; Treepongkaruna et al., 2024; Zhou & Zhou, 2021).

H_{2b}: Environment Innovation has a significant negative effect on carbon risk and a significant positive effect on stock volatility

C. METHOD

This study is a quantitative study with a causal comparative design that aims to test the effect of the Environment Innovation on stock performance proxied by stock returns and stock volatility through the mediating role of carbon risk, while incorporating profitability, firm size, industry, market value, and leverage as control variables Zhou and Zhou (2021). The data used are secondary data sourced from annual reports, sustainability reports, and stock price data of companies listed on the Indonesia Stock Exchange during the observation period thus, this study is classified as an archival study based on capital market data Bolton and Kacperczyk (2020). A comparative causal design was chosen because the study focuses on the causal relationship between environment innovation, carbon risk, and stock market performance, in

line with recent studies showing that environmental/ESG scores and carbon risk significantly influence the returns and risk of publicly traded companies (Nugraha et al, 2025).

Table 1. Measurement of Variables and Data

Variables		Formula	Source
Dependent Variable	Stock Return	$RET_t = \frac{P_t - P_{t-1}}{P_{t-1}}$	Anam et al. (2021)
	Stock Volatility	$VOL = \sqrt{\frac{1}{n}\sum_{t=1}^{n}(Rt - \bar{R})\,2}$	Ditya et al. (2025)
Independent Variable	Carbon risk	$\text{CRISK} = \frac{CO2it}{Salesit}$	Vaicondam et al. (2024)
Moderating Variable	Environment Innovation	$EI_i = \frac{1}{\text{K}}\sum_{k=1}^{K} Sik$	Hajdukiewicz and Pera (2023)
Control Variables	Return on assets	$ROA = \frac{Net\ Income}{Total\ Assets}\ x\ 100$	Febrianto and Nabila (2025)
	Return on equity	$ROE = \frac{Net\ Income}{Shareholder's\ Equity}$	Choiriya et al. (2020)
	Firm Size	$SIZE_{it} = In\ (Total\ Asset_{it})$	Hasangapon et al. (2021)
	Market Cap	$MCAP_{it} = P_{it}\ X\ Shares\ Outstanding_{it}$	Fitrah et al. (2022)
	Leverage	$LEV = \frac{Total\ Debts}{Total\ Assets}$	Farah et al. (2021)

This study uses data sources containing financial statements and related information from companies listed on the Indonesia Stock Exchange for the period 2016–2024. Data for variables such as stock returns, volatility, carbon risk, and environment innovations were collected manually and then imported manually.

Table 2. Sampling Criteria

Description	Total	
Companies registered on the Indonesia Stock Exchange	936	Companies
Companies that do not fit the criteria	860	Companies
Companies used as research samples	76	Companies
Research year	9	Year
Total research sample data	684	Data
Missing data	210	Data
Total Research Sample	**474**	**Data**

Source: Author's sample data, 2026

Based on Table 2, out of 936 companies, data from 860 companies were excluded, leaving 76 companies in the sample. The total calculation was performed using 474 data points after excluding the aforementioned data. All data variables were collected manually, and the file was subsequently processed manually. After all data variables were collected, the files were imported into Stata to perform data analysis dan test hypothesis.

The data variables were analyzed manually using a panel data regression method, an in depth analytical approach examining carbon risk and stock performance, moderated by an environment innovation. Various statistical tests, including descriptive statistics, Pearson's correlation test, regression analysis, were conducted to confirm these findings.

In this study, the dependent variable is stock performance, measured by stock return and stock volatility the independent variable is carbon risk the moderating variable is the environment innovation and the control variables include ROA, ROE, firm size, market capitalization, leverage, and industry (SIC). To analyze the effect of carbon risk on stock performance, a panel regression model was used to test this relationship. This model aims to examine how changes in carbon risk, moderated by the environment innovation, can affect stock returns and stock volatility after controlling for profitability, firm size, market capitalization, leverage, and industry.

Model 1

$$RET_{it} = \beta 0 + \beta 1\ CRISK_{it} + \beta 2\ ROA_{it} + \beta 3\ ROE_{it} + \beta 4\ SIZE_{it} + \beta 5\ LEV_{it} + \beta 6\ MCAP_{it} + \sum \beta s\ SIC_{s,it} + \mathcal{E}_{it}$$

Model 2

$$VOL_{it} = \beta 0 + \beta 1\ CRISK_{it} + \beta 2\ ROA_{it} + \beta 3\ ROE_{it} + \beta 4\ SIZE_{it} + \beta 5\ LEV_{it} + \beta 6\ MCAP_{it} + \sum \beta s\ SIC_{s,it} + \mathcal{U}_{it}$$

Model 3

$$RET_{it} = \beta 0 + \beta 1\ CRISK_{it} + \beta 2\ EIS_{it} + \beta 3\ (CRISK_{it}\ X\ EIS_{it}) + \sum \beta \mathrm{k}\ Control_{k,it} + \mathcal{E}_{it}$$

Model 4

$$VOL_{it} = \beta_0 + \beta_1\ CRISK_{it} + \beta_2\ EIS_{it} + \beta_3\ (CRISK_{it}\ X\ EIS_{it}) + \sum \beta_k\ Control_{k,it} + \mathcal{U}_{it}$$

Notes: β, are estimated parameters, i represents a firm, t denotes the time period, and the control variables include ROA, ROE, SIZE, LEV, MCAP, SIC industry code, and year.

D. RESULTS AND DISCUSSION

Descriptive statistics were used to provide an overview of the characteristics of the data used in this study. These statistics include the mean, standard deviation, and minimum and maximum values. During the 2016–2024 period, this analysis was conducted on 474 data observations from 76 companies that met the sampling criteria. Descriptive statistics for the dependent, independent, moderating, and control variables are presented in Table 3.The table shows that the average Carbon Risk (CRISK) is 6,674.425 with a very high standard deviation of 17,126.117,most issuers have relatively low carbon emissions, but there are some companies with very high carbon risk exposure.

Table 3. Descriptive Statistics

	N	Mean	Standard Deviasi	Minimum	Maximum
CRISK	474	6674.425	17126.117	48.884	116258.583
RET	474	0.001	0.007	-0.017	0.026
VOL	474	0.054	0.022	0.018	0.127
EI	474	20.220	28.146	0.000	94.643
ROA	474	0.072	0.079	-0.067	0.393
ROE	474	0.183	0.250	-0.198	1.429
SIZE	474	22.286	1.710	19.707	30.168
MCAP	474	6.237e+09	1.043e+10	61141305.151	5.885e+10

Source: Author's calculations, 2026

The average Stock Return (RET) shows a small return of 0.001, or 0.1% per period, with a standard deviation of 0.007. Observing variations in values between 0.017 and 0.026 indicates modest return fluctuations, which is reasonable for an emerging stock market like Indonesia's. Nevertheless, the average Stock Volatility (VOL) of 0.054, or 5.4%, with a

standard deviation of 0.022, indicates a relatively stable level of market risk within a range of 1.8% to 12.7%.

The average Environment Innovation (EI) is 20.220 with a standard deviation of 28.146. With a minimum score of 0 and a maximum of 94.643, there is variation in companies' capacity for environment innovation the majority of issuers have low scores, but some companies have very high scores.

Despite some unfavorable results, the control variables indicate variation in financial performance, with an average ROA of 7.2% and an ROE of 18.3%. Firm Size (SIZE) is relatively consistent, with an average of 22,286 (log of total assets), while Market Cap (MCAP) is dominated by large companies, with average values in the billions of rupiah.

Table 4. Pearson Corelation Test

	CR	SR	SV	ES	ROA	ROE	FS	MC
CRISK	1.000							
RET	0.152***	1.000						
	(0.001)							
VOL	0.124***	0.167***	1.000					
	(0.007)	(0.000)						
EI	0.065	-0.003	-0.213***	1.000				
	(0.155)	(0.949)	(0.000)					
ROA	0.028	0.038	-0.062	0.077*	1.000			
	(0.544)	(0.406)	(0.176)	(0.093)				
ROE	0.065	0.031	-0.078*	0.178***	0.712***	1.000		
	(0.160)	(0.502)	(0.088)	(0.000)	(0.000)			
SIZE	0.071	0.055	-0.096**	0.144***	-0.269***	-0.169***	1.000	
	(0.121)	(0.232)	(0.037)	(0.002)	(0.000)	(0.000)		
MCAP	-0.037	0.086*	-0.273***	0.295***	0.097**	0.141***	0.404***	1.000
	(0.422)	(0.062)	(0.000)	(0.000)	(0.034)	(0.002)	(0.000)	

p-values in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Notes: significant at α=0.10 **, significant at α=0.05 ***, significant at α=0.01.

Source: Author's calculations, 2026

Table 4 shows that Carbon Risk (CRISK) has a weak but significant positive correlation with Stock Return (RET) (r=0.152, p=0.001) and Stock Volatility (VOL) (r=0.124, p=0.007), indicating that while there is no strong correlation, an increase in carbon risk tends to be followed by an increase in stock returns and volatility. The relationship between CRISK and the Environment Innovation (EI) is also positive but not significant (r=0.065, p=0.155). This means that, based on the available data, no clear relationship between these two variables has yet been observed. The Environment Innovation (EI) is significantly negatively correlated with Stock Volatility (VOL) (r=-0.213, p=0.000), indicating a relationship between risk and returns characteristic of the stock market. Conversely, Stock Return (RET) has a significant positive correlation with Stock Volatility (VOL) (r = 0.167, p = 0.000), indicating that environment innovation can reduce stock volatility.

Return on Assets (ROA) and Return on Equity (ROE) exhibit a strong positive correlation among the control variables (r=0.712, p=0.000), while Firm Size (SIZE) and Market Cap (MCAP) show a strong positive correlation (r=0.404, p=0.000). MCAP also has a negative correlation with VOL (r = −0.273, p = 0.000), indicating that larger firms are more stable.

Baseline Regression

Tabel 5 Result of Baseline Regression

	Stock Return	**Stock Volatility**
logCRISK	0.001***	0.002***

	(3.18)	(2.96)
ROA	0.005	0.022
	(0.75)	(1.44)
ROE	-0.001	-0.004
	(-0.68)	(-1.31)
SIZE	-0.000	0.000
	(-0.20)	(0.33)
logMCAP	0.001*	-0.006***
	(1.90)	(-5.03)
_cons	-0.014**	0.181***
	(-2.01)	(7.60)
Year FE	Yes	Yes
r2	0.097	0.289
r2_a	0.072	0.269
N	474	474

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Author's calculations, 2026

The impact of carbon risk, measured using logCRISK and assessed through stock returns and stock volatility, was evaluated using a model based on the results of unmoderated regression tests in this study. In this process, control variables included ROA, ROE, firm size, and market capitalization. The results indicate that the logCRISK variable has a positive and significant impact on stock returns and stock volatility. The positive coefficients in both models indicate that the higher the carbon risk faced by a company, the higher the stock return and stock volatility. This relationship can be theoretically explained through the risk return trade off concept, where investors demand higher returns as compensation for greater risk, including environmental risk. However, rising carbon risk also reflects greater uncertainty regarding regulation, reputation, and energy transition costs, leading to greater uncertainty in the stock market. These results are consistent with the study conducted by Chen et al. (2025), which showed that carbon risk significantly affects stock returns in emerging markets. Furthermore, these findings are consistent with those of X. Ren et al. (2023), who found that carbon emissions are correlated with increased market risk and stock volatility due to heightened investor uncertainty regarding environmental policies and the transition to a low carbon economy. Further, this results implies that investors demand higher returns as compensation for greater risk, including environment risk Bolton and Kacperczyk (2020). On the other hand, increasing carbon risk also reflects uncertainty regarding regulations, reputation, and energy transition costs, thereby increasing market volatility (Luo et al., 2025; X. Ren et al., 2023). These findings are also consistent with previous research showing that carbon risk has a significant effect on stock return in emerging market Chen et al. (2025). Thus,hypotheses H1a is rejected and H1b in this study are supported (accepted).

Furthermore, based on the coefficient of determination (R^2), the model explains 9.7% of the variation in stock returns and 28.9% of the variation in stock volatility. This indicates that the model has a stronger explanatory power for stock volatility than for stock returns. A study by Miah et al. (2021) found that environmental factors are more often responsible for risk than stock return levels.

Table 6. Moderation Analysis

	Stock Return	**Stock Volatility**
logCRISK	0.001**	0.000
	(2.51)	(0.15)

logEI	0.003***	-0.006
	(3.19)	(-1.33)
ENVCAR	-0.000**	0.000
	(-2.44)	(1.29)
ROA	-0.003	-0.001
	(-0.32)	(-0.02)
ROE	-0.002*	-0.002
	(-1.71)	(-0.56)
SIZE	-0.000	-0.000
	(-0.35)	(-0.03)
logMCAP	0.001**	-0.006
	(2.45)	(-1.01)
_cons	-0.028***	0.187***
	(-3.22)	(4.94)
Year FE	Yes	Yes
r2	0.219	0.290
r2_a	0.155	0.232
N	474	474

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Based on the results of the moderation regression analysis in this study, the model was used to analyze the effect of carbon risk (logCRISK) measured using stock returns and stock volatility by including the environment innovation (logEI) as a moderating variable via the ENVCAR interaction, along with control variables such as ROA, ROE, firm size, and market capitalization.

Although the main variable logCRISK has a positive and significant effect on stock returns, it is not significant for stock volatility. This indicates that the impact of carbon risk on stock volatility is reduced when the moderating variable is included. Furthermore, the logEI variable does not have a significant effect on stock volatility, but it does have a significant positive effect on stock returns. This suggests that greater environment innovation tends to generate higher returns because it improves investors perceptions of business sustainability. However, market uncertainty is not directly reduced by environment innovation. Macchioni et al. (2024) state that environment innovation significantly influences business performance as well as the capital market.

The interaction variable ENVCAR exhibits a negative and significant coefficient regarding stock returns, but is not significant regarding stock volatility. This indicates that the environment innovation reduces the correlation between carbon risk and stock returns. In other words, companies with high levels of environment innovation have the ability to mitigate the negative impact of carbon risk on stock performance. Theoretically, environment innovation enhances investor confidence and reduces perceptions of corporate risk. These findings align with research conducted by Adu et al. (2023), who found that environment innovation and practices can moderate the relationship between environmental performance and corporate performance.

Furthermore, the coefficient of determination (R^2) values of 0.219 for stock returns and 0.290 for stock volatility indicate that the moderated model explains return variations better than the unmoderated model. Additionally, the ability to explain volatility remains relatively stable. This suggests that model quality is enhanced by adding moderating variables, particularly in explaining the relationship between carbon risk and stock returns. These results are consistent with research conducted by Miah et al. (2021), which states that environmental

factors play a significant role in determining how well a company operates, particularly regarding sustainability mechanisms and risk.

E. CONCLUSION

This study shows that carbon risk has a positive and significant effect on stock return and stock volatility, reflecting a trade off between risk and return as well as increased market uncertainty. However, the environmental innovation score was found to mitigate the impact of carbon risk on stock performance particularly on returns and to enhance positive investor perceptions. These findings underscore the importance of environmental innovation as a strategy for managing carbon risk. Implicitly, investors should consider sustainability factors in investment decisions, companies should enhance green innovation to boost market value and confidence, and governments should strengthen carbon economy policies. Theoretically, this study supports stakeholder theory, legitimacy theory, and the efficient market hypothesis, while enriching the literature on the moderating role of environmental innovation.

This study has limitations regarding sample size, the observation period, and the limited number of variables, which prevent it from fully explaining variations in stock performance. Therefore, future research is recommended to expand the sample and study period, as well as to use more comprehensive indicators and analytical methods to produce more accurate and reliable findings.

REFERENCES

Adu, D. A., Flynn, A., & Grey, C. (2023). Carbon performance, financial performance and market value: the moderating effect of pay incentives. *Business Strategy and the Environment*, *32*(4), 2111–2135. https://doi.org/10.1002/bse.3239

Agustin, I. N., Putri, I. M., & Marheni, D. K. (2026). *Revisiting EKC hypothesis through income inequality and environmental degradation in ASEAN-5 countries*. 1–21. https://doi.org/10.21831/economia.v22i1.82118

Agustin, I. N., Suhendri, N., Wang, A., & Yulfiswandi. (2024). *ESG performance and indonesia stock return*. 919–932. http://dx.doi.org/10.17509/xxxx.xxx

Akib, A., Majiding, N. C., Utami, S., Utami, D., & Ramadhani, M. W. (2025). The effect of green innovation, carbon emission disclosure, and environmental cost on company value. *Jurnal Akuntansi, Kewirausahaan dan Bisnis*, *10*(1), 38–46. http://www.ejournal.pelitaindonesia.ac.id/ojs32/index.php/KURS/index

Anam, K., Nurfadillah, M., & Fauziah, F. (2021). Analisis kinerja keuangan terhadap return saham perusahaan properti dan real estate indonesia. *Jurnal Daya Saing*, *7*.

Artika, M., Sisdianto, E., & Ekawati, E. (2025). Pengaruh emisi karbon, inovasi hijau terhadap nilai perusahaan dengan moderasi kinerja lingkungan. *Studi Ekonomi Dan Kebijakan Publik*, *4*(1), 41–56. https://doi.org/10.35912/sekp.v4i1.5456

Asih, K. N., Achsani, N. A., Novianti, T., & Manurung, A. H. (2024). Volatility of companies with low ESG scores in the Indonesian capital market: impact of domestic and global factors. *International Journal of Social Science and Business*, *8*(4), 672–681. https://doi.org/10.23887/ijssb.v8i4.88286

Bolton, P., & Kacperczyk, M. (2020). *Do investors care about carbon risk?* http://www.nber.org/papers/w26968

Chen, S., Wei, Q., & Cai, W. (2025). Carbon risk and stock return evidence from Chinese a-share listed companies. *Emerging Markets Finance and Trade*, *61*(7), 1819–1834. https://doi.org/10.1080/1540496X.2024.2444498

Choiriya, C., Fatimah, F., Agustina, S., & Ulfa, F. A. (2020). The effect of return on assets, return on equity, net profit margin, earning per share, and operating profit margin on

stock prices of banking companies in Indonesia stock exchange. *International Journal of Finance Research*, *1*(2), 103–123. https://doi.org/10.47747/ijfr.v1i2.280

Ditya, N. N., & Yanti, N. N. S. A. (2025). Return and volatility characteristics of cosmetic company stocks in Indonesia (2022-2024): a descriptive analysis. *Jurnal Ilmu Manajemen (JIMMU)*, *10*(2), 180–191. https://doi.org/10.33474/jimmu.v10i2.24199

Dussaux, D., Agnelli, A., & Es-Sadki, N. (2023). *Exploring new metrics to measure environmental innovation* (OECD Environment Working Papers, Vol. 221). https://doi.org/10.1787/e57a8a13-en

Farah, I., Amin, C., & Pramudianto. (2021). The effect of debt to asset ratio, long term debt to equity ratio and time interest earned ratio on profitability. *Bina Bangsa International Journal of Business and Management*, *1*(1), 68–78. https://doi.org/10.46306/bbijbm.v1i1.8

Febrianto, A., & Nabila, A. A. (2025). Return on asset analysis in assessing performance: transforming organizational financial performance. *Journal of Educational Management Research*, *4*(2), 697–709. https://doi.org/10.61987/jemr.v4i2.1024

Fitrah, A., Apriyanto, G., & Respati, H. (2022). Determinants of market capitalization and its effect on sharia stock return in Jakarta Islamic Index. *Business and Accounting Research (IJEBAR) Peer Reviewed-International Journal*, *6*. https://jurnal.stie-aas.ac.id/index.php/IJEBAR

Fitriana, A., Maharani, D. S., & Amelia, S. R. (2024). Pengungkapan emisi karbon dan inovasi hijau terhadap nilai perusahaan. *Prosiding Seminar Nasional Ilmu Ekonomi dan Akuntansi*, (2), 161–177.

Galama, J. T., & Scholtens, B. (2021). A meta analysis of the relationship between companies' greenhouse gas emissions and financial performance. *Environmental Research Letters*, *16*(4), 043006. https://doi.org/10.1088/1748-9326/abdf08

Hajdukiewicz, A., & Pera, B. (2023). Eco-innovation in the European Union: challenges for catching-up economies. *Entrepreneurial Business and Economics Review*, *11*(1), 145–164. https://doi.org/10.15678/EBER.2023.110108

Hasangapon, M., Iskandar, D., Purnama, E. D., & Tampubolon, L. D. (2021). *The effect of firm size and total assets turnover (tato) on firm value mediated by profitability in wholesale and retail sector companies*. *19*(3). https://jurnal.ubd.ac.id/index.php/ds

Khatib, S. F. A., Ismail, I. H. M., Salameh, N., Abbas, A. F., Bazhair, A. H., & Sulimany, H. G. H. (2023). Carbon emission and firm performance: the moderating role of management environmental training. *Sustainability*, *15*(13), 10485. https://doi.org/10.3390/su151310485

Luo, T., Luo, F., & Guo, X. (2025). Carbon risk and labor investment efficiency. *Scientific Reports*, *15*(1), 5372. https://doi.org/10.1038/s41598-025-88413-6

Macchioni, R., Fiondella, C., & Prisco, M. (2024). The value relevance of environmental innovation: Evidence from European Union context. *Journal of Cleaner Production*, *446*, 141246. https://doi.org/10.1016/j.jclepro.2024.141246

Majida, S. I., & Suwarno. (2025). Apakah inovasi lingkungan perusahaan dan profitabilitas mempengaruhi risiko jatuhnya harga saham. *Jurnal Kajian Ekonomi & Bisnis Islam*, *6*, 764–771.

Miah, M. D., Hasan, R., & Usman, M. (2021). Carbon emissions and firm performance: evidence from financial and non-financial firms from selected emerging economies. *Sustainability*, *13*(23), 13281. https://doi.org/10.3390/su132313281

Nugraha, D. A., Asimakopoulos, S., & Sudrajat, O. Y. (2025). *The impact of esg ratings on stock price and volatility: evidence from LQ45, FTSE KLCI, and FTSE STI*. *6*, 968–982. https://doi.org/https://doi.org/10.38035/dijefa.v6i2

Ott, C., & Schiemann, F. (2022). The market value of decomposed carbon emissions. *Journal of Business Finance & Accounting*, *50*(1–2), 3–30. https://doi.org/10.1111/jbfa.12616

Putri, H. D., & Agustin, H. (2023). Apakah inovasi hijau dan pengungkapan emisi karbon dapat mempengaruhi nilai perusahaan pada perusahaan manufaktur? *Jurnal Akademi Akuntansi*, *6*(1), 107–124. https://doi.org/10.22219/jaa.v6i1.22814

Rahmasari, J., & Irwansyah. (2024). Pengaruh implementasi pengungkapan emisi karbon dan inovasi hijau terhadap nilai perusahaan dengan kinerja lingkungan sebagai variabel moderasi. *INOVASI: Jurnal Ekonomi, Keuangan Dan Manajemen*, *20*(2), 345–354. https://www.idx.co.id

Ramadhan, R., Alkautsar, M., & Basit, A. A. (2025). Pengaruh pengungkapan emisi karbon, inovasi hijau dan kinerja lingkungan terhadap nilai perusahaan. *Jurnal Ekuilnomi*, *7*(2), 389–400. https://doi.org/10.36985/126evc55

Ren, S., Yang, X., Hu, Y., & Chevallier, J. (2022). Emission trading, induced innovation and firm performance. *Energy Economics*, *112*. https://doi.org/10.1016/j.eneco.2022.106157

Ren, X., Dong, Y., Guo, J. M., & Liu, Y. (2023). Institutional ownership and corporate greenhouse gas emissions: The evidence from China. *Pacific-Basin Finance Journal*, *82*, 102135. https://doi.org/10.1016/j.pacfin.2023.102135

Reshetnikova, L., Ovechkin, D., Devyatkov, A., Chernova, G., & Boldyreva, N. (2023). Carbon emissions and stock returns: The case of Russia. *Journal of Risk and Financial Management*, *16*(8), 370. https://doi.org/10.3390/jrfm16080370

Rizki, T., Widjaja, A., & Shanty, D. (2023). Carbon disclosure and SDGs performance: adoption of green innovation in Indonesia. *Jurnal Akuntansi Aktual*, *10*(2), 152. https://doi.org/10.17977/um004v10i22024p152

Sidharta, K., & Kim, S. S. (2024). The influence of esg performance on stock price volatility in Indonesia. In *Enrichment: Journal of Management* (Vol. 14, Number 3).

Treepongkaruna, S., Yong, H. H. A., & Thomsen, S. (2024). Greenwashing, carbon emission, and ESG. *Business Strategy and the Environment*, *33*(8), 8526–8539. https://doi.org/10.1002/bse.3929

Vaicondam, Y., Mustafa, A. M. A. A., Roslan, S. N. M., Ming, K. L. Y., & Ramayah, M. (2024). GHG and carbon emission intensity: examining their impact on financial performance. *International Journal of Energy Economics and Policy*, *15*(1), 190–196. https://doi.org/10.32479/ijeep.17474

Wu, A. (Angie), Subramanyam, R., & Anand, G. (2025). Carbon management practices and associations with firm performance. *Journal of Environmental Management*, *391*, 126414. https://doi.org/10.1016/j.jenvman.2025.126414

Yaqin, A. M. 'Ainul, Putri, A. A., Leksono, V. A., Setiowati, N. O., Efranto, R. Y., & Nabiha, H. D. P. (2025). Descriptive and predictive analyses of carbon emissions in Indonesia: a multifaceted approach incorporating stock market and commodity prices. *Carbon Management*, *16*(1). https://doi.org/10.1080/17583004.2025.2496482

Zahra, I. E. (2026). Inovasi hijau memoderasi hubungan carbon emission disclosure dan biaya lingkungan terhadap nilai perusahaan. *Al-Zayn: Jurnal Ilmu Sosial & Hukum*, *4*(1), 2026. https://doi.org/10.61104/alz.v4i1.4034

Zhou, D., & Zhou, R. (2021). ESG performance and stock price volatility in public health crisis: evidence from COVID-19 pandemic. *International Journal of Environmental Research and Public Health*, *19*(1), 202. https://doi.org/10.3390/ijerph19010202