Stock Market Volatility Amid the Climate Crisis: The Role of ESG as a Stability Mechanism in Asian Corporations

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ABSTRACT

This study investigates the effects of climate change exposure and environmental, social, and governance (ESG) practices on stock market volatility in Asian corporations and examines whether ESG moderates this relationship. Using panel data from 169 publicly listed companies across Asia from 2020 to 2024, the analysis applies a firm fixed effects model with robust standard errors. The results indicate that ESG practices have a negative and statistically significant effect on stock market volatility, suggesting that stronger ESG engagement contributes to lower volatility. Climate change exposure is also found to have a negative and significant effect on volatility, implying that firms with greater exposure tend to exhibit lower stock market volatility, potentially due to enhanced disclosure and risk awareness. However, the interaction term between ESG and climate change exposure is statistically insignificant, indicating that ESG implementation in Asia is not yet strong enough to offset climate risks. This study contributes to the sustainable finance literature by emphasizing the role of ESG as a risk mitigation mechanism. It provides practical insights for investors and policymakers in developing resilient and transparent financial markets amid increasing climate uncertainty.

1. INTRODUCTION

In recent years, Asian stock markets have experienced sharp fluctuations and significant volatility. These dynamics first became evident at the onset of the COVID-19 pandemic, when massive sell-offs occurred across various exchanges due to global uncertainty regarding the economic impact, mobility restrictions, and lockdown policies implemented in many countries [1, 2]. This uncertainty persisted alongside the emergence of various external challenges, including shifts in global monetary policy, inflationary pressures, and geopolitical tensions in several Asian economies. As shown in Figure 1, a pattern reflecting this volatility can be observed. Stock indices surged sharply in 2020 as markets recovered from the COVID-19 crisis, followed by a significant decline throughout 2021 to 2022, before recovering in 2023 to 2024 as the economy normalized and market activity increased.

Although global macroeconomic shocks have been widely examined as primary drivers of stock market volatility, such approaches largely capture common shocks and fail to explain firm-level heterogeneity in volatility [3]. Recent literature increasingly emphasizes that stock price volatility is shaped not only by conventional macroeconomic conditions but also by firm-specific, structural, and long-term risks, such as exposure to climate change and sustainability practices [4, 5]. Accordingly, this study conceptually examines firm-level, non-macroeconomic determinants of stock volatility.

Consistent with this perspective, climate change is increasingly recognized as a critical driver influencing financial market dynamics and stock performance in Asia. Several studies indicate that climate change exerts significant economic impacts and encourages firms to enhance transparency in disclosures [6]. Conversely, climate policy uncertainty has been shown to trigger market turbulence and increase stock market volatility [7]. The scale of this risk is reflected in the Asian Development Bank's projection that climate change could potentially reduce the Gross Domestic Product of the Asia-Pacific region by up to 41% [8]. This condition is further exacerbated by findings from the World Meteorological Organization, which reveal that temperatures in Asia are rising twice as fast as the global average, which could result in economic losses, environmental degradation, and affect daily life [9]. Recent empirical studies have emphasized that the Asian financial market's vulnerability to climate risks is compounded by inconsistent regulatory frameworks and uneven corporate disclosure quality [7, 10].

Within this context, understanding how climate risk is transmitted into firm-level stock market volatility is critical. Sautner [11] developed a firm-level climate risk exposure measure that is considered superior to conventional indicators such as carbon emissions, as it captures a broader spectrum of climate-related risks. Nevertheless, existing literature remains limited in exploring the extent to which asset prices accurately reflect climate risk [10].
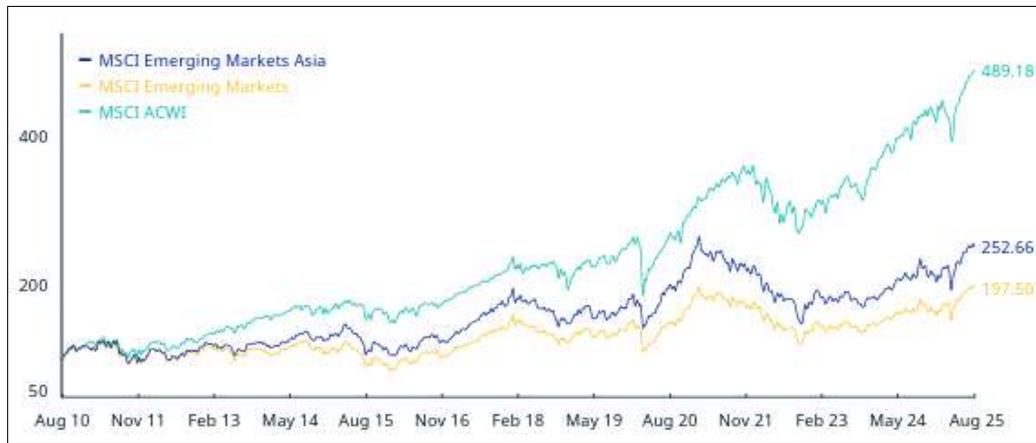
Figure 1. Cumulative index performance-net returns
Source: MSCI emerging markets Asia index

Parallel to rising climate awareness, firms have increasingly adopted environmental, social, and governance (ESG) practices. The three ESG pillars play a strategic role in shaping corporate reputation, supporting sustainable growth, and influencing investment decisions among stakeholders [12-14]. Firms with high ESG ratings are more resilient to market shocks and exhibit lower volatility, as evidenced during the COVID-19 pandemic [12, 15]. Credible ESG disclosure attracts investors and signals corporate stability and sustainability. However, ESG reporting often suffers from bias, which can undermine information validity and create uncertainty among stakeholders [16]. Similar challenges are evident in Asia, where ESG implementation continues to face barriers such as weak regulation, inconsistent reporting standards, and uneven awareness levels across countries [17-19]. These conditions may exacerbate market uncertainty and heighten asset price volatility if reporting transparency remains low.

Although research on ESG and climate risk has expanded rapidly, most prior studies have concentrated on developed markets such as the United States and Europe. At the same time, empirical evidence from Asia remains scarce. Moreover, studies that simultaneously examine the interrelationships among climate change exposure, ESG practices, and stock market volatility are still limited, particularly those employing risk-based climate change exposure measures such as the one developed by Sautner [11]. Therefore, substantial room remains for research to understand how climate change exposure and ESG performance influence stock market stability within Asia's dynamic and heterogeneous context.

Based on the context, this study aims to analyze the effects of climate change exposure and ESG practices on stock market volatility in Asia. Specifically, the study seeks to fill gaps in the literature concerning the linkages between climate change exposure, corporate sustainability practices, and firm-level financial market dynamics in Asia. In line with these objectives, this study addresses three main research questions: (1) whether climate change exposure contributes to increased stock market volatility among Asian firms; (2) how ESG practices directly affect the level of stock market volatility of Asian firms; and (3) the extent to which strong ESG practices can mitigate the impact of climate change exposure on market fluctuations and moderate the relationship between the two.

This study contributes to the sustainable finance literature by identifying the role of ESG in mitigating volatility risks arising from climate change exposure, particularly in emerging Asian markets. Practically, the findings are expected to serve as a reference for investors, regulators, and policymakers in designing green investment strategies, strengthening ESG disclosure transparency, and integrating climate risks into financial policy and corporate governance frameworks.

The following sections outline the systematic structure of this paper. The initial section presents the hypothesis formulation developed from a review of relevant literature. The methodology section then elaborates on the research process, including empirical data collection, variable determination, analytical model design, and presentation of the main results and findings. The final section discusses the results within a theoretical framework, emphasizing conceptual contributions, research limitations, and directions for future studies.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1 Theoretical background

2.1.1 Signal theory

Signaling theory [20] explains that companies use information transmission to signal investors and reduce information asymmetry in the market. In the context of sustainability, climate risk, and ESG disclosures serve as signals of a firm's commitment to environmental risk management and its readiness to adapt to regulatory and technological transitions [21, 22]. Companies that provide positive signals through ESG disclosure and climate mitigation strategies demonstrate greater strategic readiness and environmental responsibility, thereby increasing investor confidence and reducing market uncertainty [11, 14]. Conversely, a lack of transparency or inconsistency in disclosure can be interpreted as a negative signal, leading to greater perceptions of risk and increased stock volatility [6].

2.1.2 Stakeholder theory

Stakeholder theory [23] emphasizes that a company's long-term success depends heavily on its ability to meet the expectations of various stakeholders, including investors, customers, employees, and the wider community. In the context of ESG, this theory explains that social and environmental responsibility is not only a moral obligation but

also a business strategy that creates economic and social value [24, 25]. When companies demonstrate a commitment to sustainability through ESG practices, this strengthens relationships with stakeholders, reduces reputational risk, and stabilizes market confidence. Thus, consistent ESG practices have the potential to reduce stock market volatility by increasing legitimacy and investor confidence [26, 27].

2.1.3 Legitimacy theory

Legitimacy Theory holds that companies strive to maintain alignment between their activities and prevailing social values to gain acceptance [28, 29]. ESG and climate-related disclosures function as mechanisms through which firms signal compliance with sustainability expectations and regulatory standards [25]. According to this theory, companies that actively disclose social and environmental responsibilities will gain social legitimacy, strengthening the company's image and values. However, legitimacy constructed inauthentically or symbolically (window dressing) can create negative perceptions among investors and lead to market instability [30]. Therefore, the legitimacy built through ESG disclosures must be substantive and sustainable to reduce market risk effectively.

2.2 Climate change exposure and stock market volatility

Climate change has emerged as a critical global risk with significant implications for economic activity and financial markets. Both physical risks, such as extreme weather events, and transition risks, including regulatory changes and technological shifts, generate uncertainty for firms and investors, thereby influencing firm valuation, sustainability perceptions, and stock market volatility.

In the context of measuring climate risk, Sautner et al. [11] defined climate change exposure as the degree of managerial attention to climate-related impacts, opportunities, and physical and regulatory risks, as reflected in firms' discussions during earnings conference calls. This exposure captures managerial and investor perceptions of climate-related risks and opportunities, thereby serving as an important indicator for assessing firm-level risk in the transition toward a low-carbon economy.

Empirical evidence largely supports a positive association between climate change exposure and stock price volatility, as firms facing higher climate-related risks are subject to greater uncertainty and long-term vulnerability [14]. Research on China's carbon market has shown that the emissions trading system is highly responsive to global energy market dynamics, particularly during extreme climate events, which trigger surges in trading volume and market instability [20, 21]. Similarly, Bagh et al. [13] revealed that climate change risks lead to substantial economic losses and affect public financial stability in the United States.

However, this relationship is not always linear. Perera et al. [22] found that climate exposure is correlated with idiosyncratic volatility, although this relationship appears negative in some contexts. These findings suggest that markets have not yet fully priced in or efficiently absorbed information related to climate risk [23]. Consistent with this, Sautner et al. [11] showed that discussions of climate risk during earnings conference calls directly influence market volatility and firm valuation, indicating that investor reactions are highly dependent on their perceptions of risk and firms' ability to manage and communicate climate-related information.

Climate change disclosure has therefore become increasingly important in promoting sustainable development [25]. From a signaling theory perspective, the disclosure of information regarding climate risk or mitigation strategies signals investors about the extent to which firms are prepared to face policy shifts and environmental risks [24, 31]. However, according to stakeholder theory [20], various stakeholders may perceive climate change disclosures differently. Vestrelli et al. [6] found that while climate change disclosure can enhance firm value, the relationship may turn negative when public attention to climate issues intensifies, as markets associate such disclosures with higher risk and compliance costs. In this context, firms' efforts to gain social legitimacy through climate change disclosure may generate negative perceptions if investors view sustainability commitments as potentially detrimental to short-term financial performance [25, 31].

Nevertheless, the literature also suggests that increased transparency and improved understanding of climate risk do not necessarily lead to heightened volatility. Bolton and Kacperczyk [4] find that carbon risk and climate transition risk are already reflected in equity risk premia. Firms with higher quality climate disclosures and proactive mitigation strategies tend to exhibit greater stock liquidity and more controlled volatility [31, 32].

The impact of climate change exposure also varies across industries. In carbon-intensive industries, climate disclosure may increase volatility because it is perceived as an additional cost burden that constrains profitability [25]. In contrast, sectors such as renewable energy and environmentally friendly may gain competitive advantages from heightened attention to climate issues. This suggests that climate change exposure can function as both a source of risk an opportunity, depending on industry characteristics and firms' adaptive strategies. Nonetheless, the prevailing empirical and theoretical literature indicates that exposure to climate change generally increases stock market volatility, particularly when such risks are not effectively managed or disclosed.

Moreover, Asian countries face heightened climate pressure and evolving regulatory uncertainty, making financial markets in the region potentially more sensitive to climate information from other areas. Therefore, further research is warranted to examine this relationship, particularly in Asia, where market dynamics are pronounced and challenges persist in sustainability regulation and readiness for the transition toward a low-carbon economy.

H1: Climate change exposure increases stock market volatility among firms in Asian.

2.3 ESG practices and stock market volatility

Firms are increasingly motivated to adopt sustainable business practices amid growing market uncertainty and complexity. One primary approach to achieving this is implementing ESG practices, demonstrating a company's commitment to environmental, social, and corporate governance responsibility.

A growing body of empirical research supports the view that ESG practices can enhance corporate reputation, stabilize stock prices, and attract investors by signaling lower risk levels [27, 33]. Consistency in sustainability efforts and strong governance structures can improve corporate stability and reduce stock market volatility [34, 35]. In line with this,

Jeurissen [36] emphasized that a responsible business creates economic, social, and environmental value as an integral part of sustainable development. From the perspective of legitimacy theory, voluntary and transparent ESG disclosures can strengthen social legitimacy and build a positive image in the eyes of the public and investors [16, 37].

However, the effectiveness of ESG in reducing market volatility is not universal. In developing countries, high ESG scores are associated with lower weekly stock volatility, although this relationship weakens under extreme market conditions such as the COVID-19 pandemic. This shows that the external context highly influences the effectiveness of ESG as a risk reducer [38]. The shift from corporate social responsibility (CSR) to ESG has also intensified investor demand for more transparent and measurable reporting [39, 40]. Consistent with stakeholder theory, social commitment and sustainability practices are believed to enhance corporate reputation, long-term value, and financial performance by reducing reputational risk and strengthening stakeholder relationships [41, 42].

Nevertheless, the literature reveals that ESG effects are inconsistent across dimensions. In the U.S. transportation sector [43], higher ESG disclosure reduces volatility and lowers average returns, indicating a short-term trade-off. Hasanah et al. [44] and Wahyudyatmika and Astuti [45] discovered that environmental factors often reduce volatility, while the social dimension sometimes exhibits a positive correlation, and the governance aspect is not always significant. Furthermore, social issues highlighted in media coverage or online discussions can shape investor perceptions and influence stock price movements, underscoring the need for balance among ESG dimensions [46].

These diverse findings suggest that ESG is not only a reflection of corporate social and environmental responsibility but also functions as a mechanism for market risk management. In the Asian context, characterized by high sensitivity to sustainability issues and dominated by emerging markets, ESG practices may play a crucial role in maintaining stock price stability and enhancing corporate resilience against economic shocks. Based on theoretical and empirical evidence, it can be inferred that ESG practices generally tend to reduce stock market volatility. However, their effectiveness may vary depending on the ESG dimension, external conditions, and market characteristics.

H2: ESG practices reduce stock market volatility among firms in Asian.

2.4 ESG practices as a moderator between climate change exposure and stock market volatility

The growing emphasis on sustainability has encouraged firms to integrate ESG practices as strategic mechanisms to address climate risks. While climate exposure can create market uncertainty, the adoption of ESG practices is perceived to enhance corporate reputation, strengthen social capital, and build organizational resilience against external shocks [14].

Several studies support the role of ESG in enhancing corporate resilience. Chemmanur et al. [47] demonstrated that firms with higher ESG engagement exhibit greater long-term survival prospects and face lower delisting risks during extreme weather events. Moreover, companies with strong ESG practices tend to experience fewer financial constraints and enjoy improved access to capital, enhancing their

resilience amid market uncertainty. In line with these findings, Bagh et al. [13] emphasized that ESG practices can strengthen a firm's intrinsic value while improving the effectiveness of environmental risk disclosure in building investor confidence.

Furthermore, Antoniuk [31] found that high carbon and climate change disclosures increased returns above the market average. This finding aligns with Perera et al. [22], who reported that ESG practices significantly weaken the relationship between climate change exposure and idiosyncratic volatility. Some investors believe that markets have yet to fully incorporate climate risk into asset prices, suggesting that firms require credible risk management mechanisms such as ESG to counteract the underpricing of climate risks [10]. However, some investors still view ESG practices as window dressing or merely an image that has the potential to cause systematic risks due to the misalignment of company objectives with investor expectations [30]. From the legitimacy theory perspective, ESG efforts pursued solely for social legitimacy without substantive performance improvements may provoke adverse market reactions. Therefore, the quality and consistency of ESG implementation are crucial in determining its effectiveness in mitigating the adverse impact of climate change exposure on stock market volatility.

Although ESG has the potential to stabilize markets, studies directly examining its moderating role between climate change exposure and stock market volatility remain limited, particularly in emerging markets such as those in Asia, which are more vulnerable to climate risks. Accordingly, this study seeks to address this research gap and proposes the following hypothesis:

H3: ESG practices moderate the relationship between climate change exposure and stock market volatility among firms in Asian.

2.5 Control variables

This study includes three control variables to ensure the validity of the test of the effect of climate and ESG exposure on stock market volatility: company size, profitability, and leverage. Company size is used because larger companies have better business diversification, access to funding, and information transparency, thus tending to experience lower volatility. Shakil [48] included company size in the test model and found that company size directly and significantly affects stock risk. Meanwhile, Xu [49] showed that companies with substantial assets are more stable in the market, and Perera et al. [22] emphasized the importance of company size in studies of climate change exposure and idiosyncratic risk.

Return on Assets (ROA) is used as a proxy for profitability to measure a company's effectiveness in generating returns from its assets. ROA reflects a company's financial health and ability to weather market uncertainty. Zhou et al. [50] found that companies with higher profitability could suppress stock volatility during the pandemic. Also, good financial performance increases a company's resilience to climate risks and reduces stock market volatility [14].

Leverage captures financial risks that can increase a company's sensitivity to external shocks. This study uses the Debt Ratio (DR) as a proxy for leverage. Lasisi et al. [7] found that climate policy uncertainty increases market volatility, especially for companies with high debt levels. Isah et al. [51] also found that leverage amplifies the impact of climate risk

on oil market volatility. Furthermore, Chemmanur et al. [47] used leverage as a control in a study of CSR and corporate resilience during the climate crisis and pandemic. Thus, these three control variables represent fundamental company characteristics and ensure a more robust estimation of the relationship between ESG practices, climate change exposure, and stock market volatility.

3. RESEARCH METHODOLOGY

3.1 Sample and data

This study employs secondary data from 169 publicly listed firms across Asia over the period 2020 to 2024, with the observation window determined by data availability. The data collection process involved multiple stages of screening and filtering to ensure the completeness, consistency, and relevance of the variables included in the empirical analysis. The final sample comprises firms from 12 Asian countries, with a concentration in major emerging and developed markets, including China, Japan, Hong Kong, and Singapore, while the remaining firms are distributed across the United Arab Emirates, Indonesia, India, Kuwait, Malaysia, Thailand, Turkey, and Taiwan. This cross-country composition captures substantial heterogeneity in regulatory frameworks, ESG disclosure practices, and exposure to climate-related risks across the region [22, 23]. From an industry perspective, the sample spans a diverse set of sectors, including manufacturing, finance, energy and utilities, technology, and consumer-related industries. These sectors differ markedly in their ESG maturity and climate change exposure, particularly between carbon-intensive and less carbon-intensive industries. To mitigate potential biases arising from cross-country and cross-industry heterogeneity, all regression specifications include country and industry fixed effects. Asia was selected based on structural differences in capital market growth, levels of ESG disclosure, and higher exposure to climate risk compared to the Western region [22, 23].

The primary data is obtained from Refinitiv Eikon Database, including ESG scores and financial indicators for control variables. ESG performance is initially measured using a composite ESG score, which captures firms' overall sustainability performance and is widely adopted in prior empirical studies. In line with recent literature suggesting that the effects of ESG on firm risk may differ across its ESG components, additional robustness tests are conducted by decomposing the composite ESG score into its environmental (E), social (S), and governance (G) dimensions [22]. This additional analysis allows for the examination of potential heterogeneous effects across ESG pillars and ensures that the baseline findings are not driven by a specific dimension of ESG performance.

Firm-level climate change exposure (CCEXPO) is obtained from the climate change exposure dataset developed by Sautner et al. [11], which is constructed through textual analysis of earnings conference call transcripts using a bigram-based algorithm to identify the relative frequency and intensity of climate-related terms. The dataset is designed to capture the extent to which corporate management and investors pay attention to climate change–related issues. Specifically, the measure identifies three types of climate-related shocks: opportunity shocks, physical shocks, and regulatory shocks. The firm-level climate change exposure dataset is publicly available through the official Open Science Framework (OSF) website, which aims to promote scientific transparency and facilitate data reuse within the academic community.

Stock market volatility (SMVOL), as a proxy for total firm risk, is measured as the annualized standard deviation of daily stock returns [52, 53]. Although macroeconomic factors influence aggregate market volatility, the analysis focuses on firm-level mechanisms and employs a firm fixed effects model to identify within-firm variation over time [54]. Macroeconomic variables were considered in the research design; however, as aggregate shocks primarily affect firms uniformly and generate limited within-firm variation, they are not included in the baseline specification to avoid obscuring firm-specific dynamics central to this study [55]. Consistent with the firm-level focus of the analysis, the estimated effects should be interpreted as capturing firm-level associations rather than structural relationships that fully account for aggregate macroeconomic conditions.
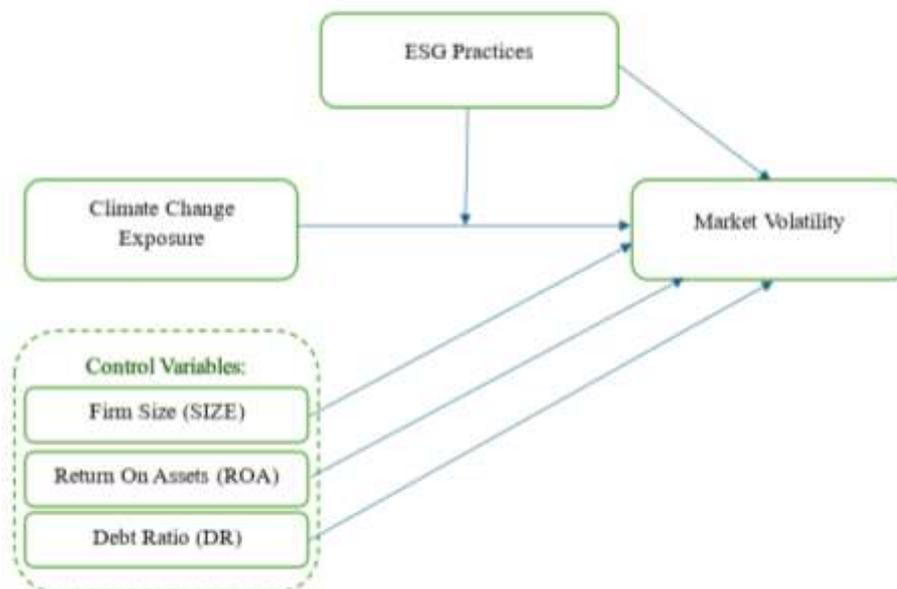

Figure 2. The relationship between variables

To address concerns regarding unobserved common shocks, additional robustness checks controlling for alternative risk measures and model specifications are reported. This study replaced the dependent variable from stock volatility (SMVOL) with market beta (BETA) as a proxy for systematic risk. Market beta is calculated as the covariance between individual stock returns and market returns divided by the variance of market returns, computed separately for each Asian stock exchange, capturing firms' exposure to aggregate market movements [48]. Moreover, recent evidence suggests that market-related risk measures are closely linked to information asymmetry and downside risk embedded in stock prices, reinforcing the relevance of beta-based risk proxies in robustness analyses [56]. While the baseline regressions employ a firm fixed effects model, the robustness specification using market beta is estimated via a random effects model, as supported by the Hausman test, which indicates no systematic difference between estimators. The relationship between variables in this study is summarized in Figure 2.

3.2 Variables measurements

The dependent variable in this study is stock market volatility (SMVOL), which reflects the level of stock price fluctuations as a proxy for the company's total risk. SMVOL is computed as the annualized standard deviation of daily stock returns, following conventional approaches in the financial literature [14, 49, 52]. This approach is widely used because it captures market instability and investor uncertainty. SMVOL is calculated using the following formula:

$$SMVOL_{it} = \sqrt{\frac{1}{N-1}\sum_{t=1}^{N}(R_{it} - \bar{R}_i)^2 \times \sqrt{T}} \qquad (1)$$

where, SMVOL represents the stock market volatility of company i on day t, Rit represents the daily return of company i on day t, and $\bar{R}_i$ is the average daily return of company i over the observation period. N refers to the total number of trading days within the period, while T represents the number of trading days in one year to annualize the daily volatility. A higher $SMVOLit$ value indicates greater dispersion in stock returns, implying higher exposure to market fluctuations and risk.

The main independent variables are ESG and climate change exposure (CCEXPO). ESG is measured using a composite score from Refinitiv Eikon, which comprehensively assesses ESG performance. This score is widely used in global studies and has been applied in empirical research on market volatility [40-49]. In addition to the composite ESG score used in the baseline analysis, this study also employs the individual environmental (E), social (S), and governance (G) pillar scores provided by Refinitiv as part of robustness tests to examine potential heterogeneity across ESG dimensions. These sub-dimensions are analyzed separately to assess whether specific ESG components drive the relationship between sustainability practices and stock market volatility. Climate change exposure is measured using a firm-level climate change exposure index developed by Sautner et al. [11], based on the frequency of climate risk terms in earnings call transcripts. This index reflects management's level of attention to climate risk and has been validated in the literature to measure a company's climate change exposure

[13, 14, 22]. This study also created an ESG×CCEXPO interaction variable to test the moderating role of ESG performance on the impact of climate change exposure on stock market volatility.

This study included three control variables to represent fundamental company characteristics. Firm size (SIZE) is measured using the natural logarithm of total assets, reflecting the scale of operations and risk diversification capacity. Firm size has been shown to reduce volatility and increase market stability [48, 49]. The formula for the SIZE is below:

$$SIZE = \ln(Total\ Assets) \qquad (2)$$

Return on Assets (ROA) is used to measure the efficiency of asset utilization in generating profits. ROA is calculated by dividing net income by total assets. This ratio indicates the company's ability to generate profit from its total assets. Higher profitability helps companies withstand external shocks and suppress volatility [14, 50]. The formula for the ROA is below:

$$ROA = \frac{Net\ Income}{Total\ Assets} \times 100\% \qquad (3)$$

The Debt Ratio (DR) reflects leverage and financial stress, measured as total liabilities divided by total assets. This ratio measures the proportion of a company's assets financed through debt. Highly leveraged companies are more vulnerable to climate policy uncertainty and stock market volatility [7, 13, 47].

$$DR = \frac{Total\ Debt}{Total\ Assets} \times 100\% \qquad (4)$$

As a robustness test, the dependent variable is replaced with market beta (BETA) to measure the sensitivity of stock returns to market returns as a proxy for systematic risk [48, 56]. BETA is calculated through a regression between stock returns and market returns using the following formula:

$$BETA_{it} = \frac{Cov(R_{it}, R_{mt})}{Var(R_{mt})} \qquad (5)$$

Rit represents the return of stock i on day t, and Rmt represents the market return on the same day. The beta coefficient $(BETAit)$ measures the systematic risk of stock i relative to the overall market, calculated as the covariance between the individual stock return and the market return divided by the variance of the market return. A higher beta value indicates the stock is more sensitive to market movements, implying greater exposure to market volatility and risk. Using SMVOL and BETA allows testing the consistency of results across two different risk dimensions.

3.3 Empirical model and estimation techniques

This study examines the effect of ESG practices and climate change exposure on stock market volatility in Asian companies using a panel data regression approach because it can capture dynamics across time and differences in characteristics between companies. A Hausman test was conducted to determine the appropriate model between fixed effects (FE) and random effects (RE). The test results indicate that the fixed effects model is more suitable. Estimation uses

clustered robust standard errors to address heteroscedasticity and autocorrelation in panel data. All financial variables are winsorized at the 1% and 99% percentiles to reduce the influence of outliers. This study estimates the following regression model:

$$SMVOL_{it} = \alpha + \beta_1 CCEXPO_{it} + \beta_2 ESG_{it} \\ + \beta_3 CCEXPO \times ESG_{it} + \beta_4 SIZE_{it} \quad (6) \\ + \beta_5 ROA_{it} + \beta_6 DR_{it} + \varepsilon_{it}$$

The regression includes the main variables of stock market volatility *(SMVOLit)*, climate change exposure *(CCEXPOit)*, and ESG practices *(ESGit)*. An interaction term between *CCEXPOit* and *ESGit* is included to examine the moderating effect of ESG practices on the relationship between climate change exposure and stock market volatility. In addition, several firm-level control variables are employed, including firm size *(SIZEit)*, profitability *(ROAit)*, and leverage *(DRit)*, to account for potential differences in company characteristics that may influence volatility behavior. εit is the error term.

As an additional robustness checks, the baseline model is re-estimated by replacing the composite ESG score with its ESG components [22], and by substituting stock market volatility with market beta as a proxy for systematic risk [48, 56]. The use of market beta as an alternative risk proxy allows for verification of the consistency of empirical results and increases the reliability of research findings.

4. RESULT AND DISCUSSION

4.1 Descriptive statistics

Table 1 provides an overview of the characteristics of the variables used in this study. The primary dependent variable, stock market volatility (SMVOL), has an average value of 0.334 with a standard deviation of 0.113, indicating that stock price fluctuations among firms are at a moderate level. The minimum value of 0.149 and the maximum value of 0.713 suggest substantial variation in total market risk across firms in the sample. The market beta (BETA) shows an average of 0.902 with a standard deviation of 0.369, implying that most firms exhibit relatively high sensitivity to aggregate market movements. This provides a relevant foundation for comparing total and systematic risk behaviors in subsequent model estimations.

Table 1. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
SMVOL	845	0.334	0.113	0.149	0.713
BETA	845	0.902	0.369	0.148	1.814
ESG	845	65.316	14.204	27.17	89.32
CCEXPO	845	0.003	0.004	0	0.024
SIZE	845	16.564	1.847	13.222	21.792
ROA	845	0.056	0.063	-0.08	0.275
DR	845	0.243	0.18	0	0.744

The primary independent variable, ESG score, has an average value of 65.316, ranging from 27.17 to 89.32, reflecting that most firms have implemented relatively strong sustainability practices. Meanwhile, climate change exposure (CCEXPO) records a very low mean value of 0.003 with a range extending up to 0.024, indicating that corporate

transparency regarding climate risks remains limited, despite observable variation among firms.

Regarding the control variables, firm size (SIZE) has an average value of 16.564, suggesting that most firms in the sample are medium to large in scale. Profitability (ROA) shows an average of 0.056, representing a moderate level of earnings performance. Leverage (DR) records an average value of 0.243, implying that firms generally maintain a conservative capital structure, although some exhibit debt ratios as high as 74%.

Variance Inflation Factors (VIF) were calculated to assess potential multicollinearity. As presented in Table 2, all VIF values are below the commonly accepted threshold of 5, suggesting the absence of severe multicollinearity among the variables. The highest VIF value was found for ROA (1.459), while the lowest was for CCEXPO (1.034).

Table 2. Variance inflation factors (VIF)

	VIF	1/VIF
ROA	1.459	0.686
SIZE	1.302	0.768
DR	1.207	0.828
ESG	1.044	0.958
CCEXPO	1.034	0.967
Mean VIF	1.209	.

Table 3 illustrates the pairwise correlation coefficients among the study variables. All coefficients are below 0.90, confirming that multicollinearity is not a concern within the dataset.

Table 3. Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) SMVOL	1.000						
(2) BETA	0.551	1.000					
(3) ESG	-0.146	-0.078	1.000				
(4) CCEXPO	0.011	0.055	0.031	1.000			
(5) SIZE	-0.051	0.065	0.181	0.105	1.000		
(6) ROA	-0.115	-0.083	-0.002	-0.111	-0.439	1.000	
(7) DR	0.160	0.154	0.031	0.158	0.128	-0.392	1.000

Overall, the descriptive statistics and correlation results indicate adequate variability in firm risk and characteristics within the sample. The preliminary findings also provide empirical support that ESG practices, climate change exposure, and financial factors such as leverage and firm size potentially influence stock market volatility and systematic risk. The next step is to test these relationships causally through panel regression analysis.

4.2 Regression results

The estimation results of the Fixed Effect Model (FEM) presented in Table 4 indicate that ESG has a negative and significant effect on stock market volatility (SMVOL), with a coefficient of -0.003. This finding suggests that stronger ESG practices are associated with lower volatility in stock prices, implying that firms engaging more actively in sustainability practices tend to experience greater market stability.

Similarly, climate change exposure (CCEXPO) also negatively and significantly affects SMVOL, with a coefficient of -4.703. This result indicates that firms with greater transparency and responsiveness toward climate risks

tend to have lower stock market volatility, which may reflect investor confidence in firms that proactively manage climate risks.

Table 4. Regression results

SMVOL	Coef.	St.Err.	T-Value	p-Value	[95% Conf	Interval]	Sig
ESG	-0.003	0.001	-2.70	0.008	-0.004	-0.001	***
CCEXPO	-4.703	2.121	-2.22	0.028	-8.89	-0.516	**
CCEXPO×ESG	0.015	0.1	0.15	0.878	-0.181	0.212	
SIZE	-0.132	0.039	-3.41	0.001	-0.208	-0.056	***
ROA	-0.017	0.137	-0.13	0.9	-0.287	0.252	
DR	0.325	0.095	3.42	0.001	0.137	0.514	***
Constant	0.271	0.027	9.94	0	0.217	0.324	***

Mean dependent var	0.334	SD dependent var	0.113
R-squared	0.183	Number of obs	845
F-test	11.500	Prob > F	0.000
Akaike crit. (AIC)	-1998.303	Bayesian crit. (BIC)	-1969.867

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

Regarding the control variables, the findings are consistent with established financial theory. Firm size (SIZE) has a negative and significant coefficient (-0.132), confirming that larger firms, due to their diversified operations and stable earnings, experience lower volatility. In contrast, leverage (DR) shows a positive and significant effect (0.325), suggesting that higher debt levels increase firms' sensitivity to external shocks and market risk. Meanwhile, profitability (ROA) has a negative but insignificant coefficient (-0.017), implying that while profitability may contribute to stability, its impact on volatility is not statistically robust. The model's R-squared value of 18.3% indicates moderate explanatory power, which is common in firm-level panel regressions of stock market volatility. This level of fit reflects the inherently complex and multifactor nature of volatility, which is influenced not only by firm-specific climate and ESG factors but also by macroeconomic conditions, policy shocks, and market-wide dynamics that are intentionally not included in the baseline specification to preserve within-firm identification. Consistent with prior empirical studies using cross-sectional and panel data in finance, the primary objective of the model is to identify statistically and economically meaningful relationships rather than to maximize overall explanatory power.

When the moderating variable was incorporated into the model, the interaction coefficient (CCEXPO×ESG) was positive but insignificant (0.015). This implies that ESG does not significantly moderate the relationship between climate change exposure and stock market volatility. However, the positive direction of the coefficient suggests a slight tendency for ESG to weaken the stabilizing effect of climate change exposure on volatility, though this effect lacks statistical significance.

This outcome may reflect heterogeneous investor perceptions regarding ESG practices in the context of climate risk. While ESG engagement is generally associated with lower risk and greater resilience, investors may interpret ESG efforts differently, particularly if they perceive such initiatives as symbolic rather than substantive, diminishing their moderating influence in the relationship between climate change exposure and stock market volatility.

4.3 Robustness check

As a robustness check, this study employs an alternative measure of risk by replacing stock market volatility (SMVOL), which captures total firm-level risk, with market beta (BETA) as a proxy for systematic risk. Table 5 presents the estimation results for baseline models without the interaction term and extended models incorporating the interaction between climate change exposure (CCEXPO) and ESG performance. All robustness estimations are conducted using a Random Effects Model, as the Hausman test does not reject the null hypothesis, indicating that the Random Effects estimator is both consistent and efficient.

Table 5. Robustness analysis using market beta as an alternative risk measure

Variable	(1) SMVOL Baseline Model	(2) BETA Baseline Model	(3) SMVOL Interaction Model	(4) BETA Interaction Model
ESG	-0.0026***	-0.001	-0.0026***	-0.001
CCEXPO	-4.6822**	-0.885	-4.7030**	-0.740
SIZE	-0.1321***	0.004	-0.1320***	0.004
ROA	-0.017	-0.208	-0.017	-0.208
DR	0.3246***	0.3095***	0.3255***	0.3080***
CCEXPO×ESG			0.015	-0.111
cons	0.2707***	0.8409***	0.2706***	0.8410***

Legend: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

The results show that neither ESG nor CCEXPO has a statistically significant effect on BETA, although the estimated coefficients remain negative and consistent with the baseline SMVOL models. Leverage (DR) has a significant positive impact on both the SMVOL and BETA models. Meanwhile, firm size (SIZE) is significant and negative on SMVOL but insignificant on BETA. Profitability, measured by ROA, remains negative but insignificant in both models. The interaction between CCEXPO and ESG remains insignificant in both models. This indicates that ESG does not moderate the effect of climate change exposure on risk, either total risk or systematic risk.

Overall, the robustness analysis confirms the conceptual consistency of the main findings, as the direction of the estimated relationships remains stable across alternative risk measures. However, the loss of statistical significance in the BETA models suggests that climate change exposure and ESG practices primarily affect firm-specific, controllable risk rather than market-wide systematic risk, highlighting differences in risk transmission mechanisms within financial markets.

In addition to the robustness test using market beta, this study further examines the stability of the baseline results by decomposing the composite ESG score into its ESG dimensions. Specifically, the baseline fixed-effects regression is re-estimated by replacing the composite ESG variable with each ESG dimension separately, while maintaining the same set of control variables and firm-level fixed effects. As reported in Table 6, all ESG pillars are negatively associated with stock market volatility, with the environmental and governance dimensions exhibiting relatively stronger effects. These findings suggest that the volatility-reducing role of ESG is not homogeneous across its components and is primarily driven by environmental risk management and governance quality. This result is consistent with prior studies documenting heterogeneous ESG effects, where

environmental and governance practices play a more prominent role in mitigating firm-level risk and market uncertainty [4, 22, 57].

Table 6. Robustness analysis using environmental, social, and governance dimensions

Variable	Environmental Model	Social Model	Governance Model
E		-0.0025***	
S		-0.0013**	
G		-0.0011***	
CCEXPO	-4.1422**	-4.7964**	-5.1548**
SIZE	-0.1175***	-0.1426***	-0.1478***
ROA	0.014	-0.033	-0.018
DR	0.3446***	0.3449***	0.3289***
_cons	0.2625***	0.2670***	0.2713***

Legend: * $p < -0.1$; ** $p < 0.05$; *** $p < 0.01$

4.4 Discussions

4.4.1 Climate change exposure on stock market volatility

The results of this study indicate a different direction from the initial hypothesis, showing that climate change exposure has a significant adverse effect on stock market volatility in Asian. Although conventional climate finance literature argues that climate risk and climate policy uncertainty generally amplify market volatility by increasing uncertainty and required risk premiums, a growing body of evidence shows that this relationship is highly context-dependent [7, 13, 14]. Moreover, the market still does not fully factor climate risk into asset valuations, resulting in delayed or inefficient market responses to climate risk [10]. This indicates that markets remain imperfect in processing and absorbing climate risk information [23]. Such limited incorporation of climate risk into asset prices can be attributed to structural inefficiencies, heterogeneous disclosure practices, and differences in investor sophistication across Asian capital markets.

From a market efficiency perspective, prior studies document that many Asian equity markets adjust more slowly to new risk information due to differences in investor sophistication, regulatory enforcement, and disclosure quality [58]. In such environments, increased attention to climate-related risks can improve price discovery by clarifying firms' long-term exposure and transition strategies. This interpretation is consistent with Perera et al. [22] and Antoniuk [31], who find that firms with higher climate exposure experience lower idiosyncratic volatility when climate information is communicated transparently and perceived as credible. Similar evidence is provided by Pankratz et al. [57] and Bolton and Kacperczyk [4], who show that climate risk is increasingly priced through expected returns rather than short-term volatility as investors become more forward-looking.

In the Asian context, several countries, such as Japan, South Korea, and Singapore, have implemented climate change disclosure regulations based on the Task Force on Climate-related Financial Disclosures (TCFD). Prior evidence shows that enhanced climate disclosure reduces information asymmetry and stabilizes investor expectations, such that climate change exposure accompanied by credible disclosure functions as a risk-resolving signal rather than a source of market instability [21, 24].

Thus, this study's results demonstrate the asymmetric impact of climate change exposure on stock market volatility. Climate change exposure accompanied by robust disclosure can reduce volatility through investor confidence. These findings offer a significant contribution by confirming that the impact of climate risk depends on the quality of disclosure, not just the level of exposure itself.

4.4.2 ESG practices on stock market volatility

This study found that ESG practices significantly adversely affect stock market volatility in companies in the Asian region, thus accepting the second hypothesis. This finding confirms that ESG acts as a market risk mitigation mechanism.

In line with stakeholder theory [26], companies implementing sustainability practices tend to have better stakeholder relationships, more transparent governance, and stronger legitimacy. This condition minimizes information asymmetry, reduces reputational risk, and decreases market uncertainty. This finding is also consistent with previous empirical studies, which show that ESG reduces stock volatility, especially during periods of global uncertainty, because ESG increases a company's resilience to external shocks [12, 14].

Overall, this study's findings reinforce the view that ESG practices are not merely a reputational strategy but a part of effective financial risk management in Asian markets. Thus, ESG is essential in reducing stock market volatility and enhancing long-term corporate stability.

4.4.3 ESG practices as moderation of climate change exposure and stock market volatility

This study shows that ESG does not moderate the relationship between climate change exposure and stock market volatility, thus rejecting the third hypothesis. Although the interaction term coefficient is positive, the effect is not statistically significant, indicating that ESG only slightly attenuates the impact of climate change exposure, but is not strong enough to be an effective moderator. This may reflect uncertainty or differences in investor perceptions of ESG in the context of climate risk in Asian markets.

Several contextual factors can explain this insignificance. ESG implementation in many Asian countries remains broad-based and does not focus on mitigating specific climate risks, thus not producing a synergistic effect with climate change exposure. Furthermore, investors in Asian markets tend to view climate change exposure and ESG practices as two separate signals, rather than complementary mechanisms. Differences in the quality of sustainability reporting and regulations across Asia contribute to the variance that weakens the moderating effect in this study.

Thus, ESG practices effectively reduce stock market volatility but are not strong enough to moderate climate change exposure. These findings extend the literature by demonstrating that the impact of ESG depends on the context and design of its implementation. This research also emphasizes the importance of ESG policies, focusing more on climate issues than just formal corporate compliance, in the Asian region.

5. CONCLUSIONS

This study examines the influence of climate change exposure and ESG practices on stock market volatility in the Asian region, as well as the moderating role of ESG in the

relationship. The results indicate that climate exposure and ESG practices significantly affect stock market volatility, supporting the idea that disclosure can strengthen legitimacy, reduce information asymmetry, and enhance market stability [12, 26, 49]. However, ESG does not moderate the relationship between climate change exposure and stock market volatility, suggesting that ESG's role in the Asian region remains indirect, mainly due to regulatory heterogeneity and implementation quality [13, 14].

From a theoretical perspective, this study extends the literature on sustainable finance and climate risk, confirming that ESG risk disclosure and practices mitigate market volatility. Practically, the findings emphasize the importance of integrating ESG and climate mitigation strategies into corporate policies to strengthen market resilience and attract long-term investors.

While this study makes a significant empirical contribution, several limitations should be acknowledged. The sample size is limited to companies in Asian, so the results may not fully represent the global market with its diverse regulatory and governance characteristics. Furthermore, the measurement of ESG and climate change exposure is based on aggregated secondary data, which may obscure variations in reporting quality across companies and fail to capture the depth of sustainability practices and individual dimensions of ESG practices.

Future research should expand the scope of cross-regional market analysis by considering the interaction effects of macroeconomic and climate factors. Furthermore, longitudinal testing using dynamic models can provide a deeper understanding of the long-term effects of sustainability on market risk. Therefore, developing more comprehensive and contextually based studies is expected to deepen our understanding of climate transparency and ESG practices as risk mitigation tools and foundations for Asian financial market stability amidst global uncertainty.

DATA AVAILABILITY

The data supporting the findings of this study are openly available in the Zenodo repository and can be accessed via https://doi.org/10.5281/zenodo.18208887.

AUTHOR CONTRIBUTIONS

Franciska Apriliawati: Conceptualization, Methodology, Investigation, Software, Formal Analysis, Resources, Data Curation, Writing Original Draft, Visualization, Project Administration. Lindrianasari: Conceptualization, Methodology, Validation, Formal Analysis, Resources, Writing Review & Editing, Visualization, Supervision, Project Administration.

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