Impact of Flood and Storm Events on the Asian Technology Sector: A Stock Market Reaction Study with a Sustainable Finance Perspective

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Abstract (EN)

This study examines the stock market impact of climate-related disasters on Asian technology firms, assessing whether ESG scores, CO_2 emissions, and firm characteristics influence firms' resilience to such events. Using an event study methodology, we analyze cumulative abnormal returns (CAARs) across multiple event windows and apply CAPM and Fama-French Five-Factor (5FF) regressions to assess the role of ESG in moderating financial shocks.

The findings indicate that extreme weather events negatively impact stock returns, with larger firms experiencing greater losses. ESG scores show a weakly significant positive correlation with CARs, suggesting that sustainable business practices may enhance investor confidence post-disaster. Among ESG components, the Social Pillar exhibits the strongest relationship with stock resilience. Conversely, firms with high Scope 3 CO_2 emissions face stronger negative reactions, highlighting investor concerns over supply chain vulnerabilities.

Keywords: Asian Market, Technology Sector, Natural Disasters, Event Study

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Abstract (PT)

Este estudo analisa o impacto dos eventos climáticos no mercado de ações de empresas tecnológicas asiáticas, avaliando se as classificações ESG, as emissões de CO_2 e as características das empresas influenciam a sua resiliência a esses eventos. Utilizando a metodologia de estudo de eventos, analisamos os retornos anormais acumulados (CAARs) em múltiplas janelas temporais e aplicamos regressões CAPM e Fama-French Five-Factor (5FF) para avaliar o papel da classificação ESG na atenuação de choques financeiros.

Os resultados indicam que eventos climáticos extremos impactam negativamente os retornos das ações, com as maiores empresas a sofrerem perdas mais acentuadas. As classificações ESG apresentam uma correlação positiva fraca, mas positiva, com os CAARs, sugerindo que práticas empresariais sustentáveis podem fortalecer a confiança dos investidores após um desastre. Entre os componentes do ESG, o Pilar Social revela a associação mais forte com a resiliência do mercado. Por outro lado, empresas com elevadas emissões de CO_2 no âmbito do Scope 3 enfrentam reações negativas mais intensas, refletindo as preocupações dos investidores com vulnerabilidades na cadeia de abastecimento.

Keywords: Mercado Asiático, Setor Tecnológico, Desastres Naturais, Estudo de Eventos

Title: Impacto de Inundações e Tempestades no Setor Tecnológico Asiático: Um Estudo da Reação do Mercado de Ações numa Perspectiva de Finanças Sustentáveis

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1. Introduction

Asia is facing increasing economic consequences from extreme weather events, such as floods and storms, which go beyond direct environmental damage. Recognizing that the complex link between climate risk and financial stability is becoming critical in an era of increased awareness of sustainability and corporate responsibility, investors and analysts must negotiate the disruptions these events cause to supply chains, asset values, and consumer behavior. Understanding this relationship is essential for adapting investment strategies and ensuring long-term financial resilience in the face of a changing climate.

In the Asian context, climate-related risks, such as floods and storms, have become significantly more important for financial markets. Research has shown that these events not only disrupt industrial operations but also influence market volatility and investment flows. Mahalingam (2018) emphasizes how severe natural catastrophes that are highly destructive, such as storms, trigger financial market volatility by reshaping investor risk assessments and disrupting supply chains. According to Oloko (2022), climate change risks have a mixed impact on stock markets in Asia: as climate change tends to reduce stock returns in 40% of the market, increase in about 20%, and show no significant impact on about 40%, particularly through their effect on investor sentiment and confidence. Thus, Tianyin (2022)'s Ecosperity[1] emphasizes how Asian nations' geographic location increases their likelihood of being exposed to climate events; therefore, financial institutions in Asia, including the central bank of South Korea, are starting to systematically assess and price climate risks to better equip themselves for their economic consequences.

This paper investigates how floods and storms affect Asian technology, specifically tech hardware and software. I examine stock market response to 30 significant climate events in China, South Korea, and Japan using an event study approach. Additionally, I analyse whether ESG scores influence abnormal returns and whether firms with higher ESG ratings or lower CO_2 Emissions experience smaller losses, using a series of progressive regressions.

The thesis is structured as follows: Section II surveys the existing literature and discusses climate events' impact on markets. Section III outlines the methodology, specifically discussing

[1] Ecosperity is Temasek's global platform for sustainability engagement and advocacy. As a Singapore-based global investment firm, Temasek integrates ESG considerations into its long-term value strategies. Through Ecosperity, it collaborates with global leaders to share best practices, drive collective action, and promote sustainability. This platform reflects Temasek's commitment to tackling climate change, resource efficiency, and inclusive growth, reinforcing sustainability as a core pillar of its investment philosophy.

the event study framework. Section IV discusses the results and focuses on analysing market reactions. Section V examines the study limitations and future research. Finally, section VI concludes by summarizing the main findings of my work linking it to prior studies.

2. Literature Review

2.1 Asia and Natural Disasters

Monsoons[2] are seasonal climatic phenomena that have a significant impact on East Asian weather patterns, particularly in China, South Korea, and Japan, claimed by (Kyung-Ja-Ha et al, 2012). The impact of monsoon events has intensified due to climate change. For example, severe floods and landslides throughout Asia caused more than 100 lives in July 2023.

According to a 2024 World Meteorological Organization (WMO, 2024) analysis, Asia is the continent most susceptible to natural disasters. The study highlights how Asia is warming more quickly than the rest of the world due to climate change, which raises the frequency and severity of climate-related events. Asia is leading the world in the climate crisis, with risks increasing annually, underscoring the need to comprehend and decrease the financial and social effects of these calamities. Asia's vulnerability to these climate risks is particularly pertinent as this thesis examines the financial effects of floods and storms on the region's technology sector, with a focus on how these events disrupt financial stability and how ESG factors might act as a buffer against such shocks.

2.2 Tech Hardware and Software Subsectors in Asia

The technology hardware and software industries are vital to the economies of China, South Korea, and Japan because they promote innovation, employment opportunities, and global competitiveness. Because of their significance, it is critical to assess how climate events impact these industries because disruptions can have a significant impact on both local and global economies.

The interaction between the hardware and software industries in Japan, China, and South Korea defines Asia's leadership in the tech sector and solidifies the importance of this study in understanding the impact of the increasing climate disasters and how ESG practices can help diminish such negative effects in this sector.

[2] Monsoons involve wind shifts that create distinct wet and dry seasons, shaping regional climates.

The hardware and software sectors in Asia are particularly vulnerable to floods and storms due to their geographic locations and industry structures. The Yangtze River Delta[3]—a major hub in China for electronics manufacturing[4]— is vulnerable to seasonal flooding, which has past caused disturbance of production facilities and worldwide supply networks. For example, the region's severe floods in 2020 caused factories to temporarily close, which affected tech giants and delayed shipments everywhere. Thailand's 2011 floods also highlight the severe effect that flooding has on global supply chains, particularly in the technology sector. Since Thailand is a major producer of hard disk drives, its output was significantly disrupted, leading to shortages and higher prices for goods everywhere.

The semiconductor industry in South Korea is at risk from typhoons and heavy rains that damage power and infrastructure needed for chip manufacturing. Similarly, Typhoon Hagibis in 2019 disrupted coastal high-tech manufacturing in Japan, highlighting the need for disaster awareness, robust infrastructure, and further research on the financial impact of these events to reduce economic risks in these crucial sectors.

In order to provide insight into how environmental factors impact financial stability and investor behavior, this paper will examine the resilience and vulnerabilities of these subsectors through an analysis of stock market responses to major flood events.

2.3 ESG Scores and Their Role in Market Resilience to Natural Disasters

Environmental, social, and governance (ESG) ratings are key indicators of a company's sustainability and resilience to external shocks. Strong ESG businesses typically exhibit greater flexibility to satisfy the demands of investors and meet regulations. This study examines whether Asian technology companies with higher ESG ratings experience less severe stock price declines after floods and storms.

While many studies have already analysed the relationship between ESG performance and firm performance, there is limited research on how ESG scores influence the severity of the impact of climate events on firms.

[3] The Yangtze River Delta (YRD) is one of China’s most economically dynamic regions.
[4] Manufacturing hubs are highly vulnerable to extreme weather, which can damage infrastructure, halt production, and delay shipments. Power outages, facility flooding, and raw material losses further disrupt tech companies, with semiconductor production losses impacting electronics and other industries.

Prior studies offer mixed perspectives. Some find that ESG enhances resilience (Dimson, 2015) shows that firms with high ESG engagement improve profitability and governance, while Albuquerque (2020) and Flammer (2015) report that firms with strong ESG scores performed better during the 2007-2008 financial crisis, maintaining investor trust and reducing volatility. The results indicate that ESG-focused risk management could decrease the negative effects of environmental disturbances on stock prices.

However, (Bolton & Kacperczyk, 2021) argues that carbon emissions and ESG considerations are increasingly integrated into investors' evaluation processes, reflecting that investors actively assess climate-related liabilities. Nonetheless, (Renneboog et al., 2008) and (Margolis et al., 2007), find no significant correlation between ESG and financial performance. Critics such as (Friedman, 1970) and (Jensen & Meckling, 1976) further state that ESG operations could take attention away from profit maximizing, lowering the value of the company.

Research on ESG's role in disaster resilience is growing. Shackleton (2022) conducted an event study on billion-dollar hurricanes in the U.S. and found that firms with high ESG scores experienced less severe stock declines. Similarly, Dyck (2019) and Pedersen (2021) argue that ESG-driven investment strategies enhance risk-adjusted returns and improve market positioning. However, gaps remain- many studies examine how disasters influence ESG practices, rather than how ESG affects stock price reactions to these events.

There is growing research on the potential benefits of ESG in improving disaster resilience. (Shackleton, 2022) found that companies with high ESG ratings experienced less severe stock declines in his event study on billion-dollar hurricanes in the United States. Similarly, ESG-driven investment strategies strengthen market positioning and raise risk-adjusted returns, according to (Dyck et al., 2019) and (Pedersen et al, 2021). However, there are still gaps that we plan to assess; many studies focus on the impact of disasters on ESG practices rather than how ESG influences stock price reactions to these occurrences.

2.4 ESG in Asian Markets and Its Role in Climate Resilience

South Korea, China, and Japan are important technological hubs where ESG adoption varies based on regulatory and economic frameworks. Compared to Western economies with standardized ESG models, Asian markets rely more on cultural norms that emphasize long-term sustainability.

The impact of ESG on financial resilience varies across regions. Liu (2023) found that Japanese firms with higher ESG scores experienced lower volatility and improved liquidity during COVID-19 crisis, reinforcing ESG's role in stabilizing investor confidence during economic downturns. Similarly, Tang (2020) and Dyck (2019) highlight that strong ESG strategies improve market performance, particularly during crises, by attracting institutional investors and improving risk management.

Despite extensive research on ESG's long-term benefits, few studies assess its role in moderating stock market reactions to climate shocks.

This study seeks to fill this gap by analysing whether firms with stronger ESG credentials or lower CO_2 emissions exhibit greater stock price resilience following extreme weather events, contributing to the growing discussion on sustainable investing and climate risk management.

3. Methodology

We apply an event study method, using two predictive models over a 250-day window to estimate parameters. These are then used to compute expected returns and abnormal returns by comparing realized returns to expectations during the event window.

The event date is defined as the first landfall of the storm or flood, or the next trading day if it falls on a non-trading day.

This methodology builds on prior research, such as (Shackleton, 2022), which used event studies to assess financial impacts of billion-dollar hurricanes, and (Kryzanowski et al., 2017)which analyzed stock returns and volatility following natural disasters.

To complement the analysis, we conduct regressions incorporating Environmental, Social, and Governance (ESG) factors and CO_2 emissions as key variables, progressively controlling for firm size, liquidity, and other financial metrics, following approaches like (Lins, 2017), which integrates ESG performance with financial factors in event studies.

This methodology assumes market efficiency (Fama E. , 1970), meaning stock prices should immediately reflect the impact of climate events if investors perceive them as financially relevant.

3.1 Data Collection

3.1.1 Stock Prices and Returns

Daily stock price data between 01/01/2009 to 30/08/2024 for tech sector companies in Japan, South Korea, and China were retrieved from the LSEG Workspace [5]database.

Companies with less than 250 days of pre-event data were dropped. Observations decreased due to missing ESG Score and CO_2 Emissions data, but the dataset remains substantial, with the number of observations as follows: 2,740 (Japan), 4,288 (South Korea), and 942 (China), totalling 7,970 observations.

Table 1 summarizes CAARs across event windows, showing country-specific variations. Japan exhibits the most stable returns (lowest standard deviation), while South Korea shows greater volatility, with a wider range between minimum and maximum CAR values. The large sample size reinforces the study's robustness.

	Mean	Std.	Min	Max	Total Observations
China					2740
CAPM CAAR [-5,10]	-.0316451	.1247173	-.7010537	.3634495	
CAPM CAAR [-10,10]	-.0247344	.1452199	-.7308433	.4153214	
CAPM CAAR [-5,5]	-.0179213	.1050588	-.4696907	.3069456	
5FF CAAR [-5,10]	-.0238216	.1390853	-.7155043	.6964073	
5FF CAAR [-10,10]	-.0175726	.1360328	-.7435321	.434207	
5FF CAAR [-5,5]	-.0235735	.1002251	-.503875	.2548965	
Japan					4288
CAPM CAAR [-5,10]	-.0028022	.1062577	-.6339848	.5171973	
CAPM CAAR [-10,10]	-.0240617	.1251773	-.6036066	.510186	
CAPM CAAR [-5,5]	-.0091295	.0813166	-.3887873	.439024	
5FF CAAR [-5,10]	.0119058	.0991694	-.3579989	.5049717	
5FF CAAR [-10,10]	-.0047521	.1170266	-.5582082	.4900179	
5FF CAAR [-5,5]	.002757	.0813136	-.3964861	.4377385	
South Korea					942
CAPM CAAR [-5,10]	.0065777	.1428216	-.6287805	.946052	
CAPM CAAR [-10,10]	-.0135137	.1650222	-.7885563	.9997905	
CAPM CAAR [-5,5]	-.0145294	.1150029	-.4208673	1.037591	
5FF CAAR [-5,10]	.0033665	.1434192	-.5802576	.9125128	
5FF CAAR [-10,10]	-.0146221	.1661029	-.8288259	.9757665	
5FF CAAR [-5,5]	-.0205738	.1186255	-.4454764	.9875248	
					Total: 7970

Table 1- Summary Statistics per Country and Nº of Observations

[5] LSEG is a global financial market infrastructure and data provider, specializing in analytics, indices, capital markets, trade execution, clearing, and risk management. Its five divisions—Data & Analytics, FTSE Russell, Risk Intelligence, Capital Markets, and Post Trade—offer a broad range of services. Headquartered in London, it operates across Europe, the Americas, Asia-Pacific, and emerging markets.

Expected returns were calculated using CAPM and the 5FF model, followed by CAAR computations across multiple event windows (Table 2).

For all three event windows, mean CAARs are negative across both models, indicating an overall negative market reaction to the events under study. CAPM CAARs vary from -0.012 to -0.023, while 5FF CAARs, closer to zero, vary between -0.002 to -0.01. The consistently lower mean than median suggests a left-skewed distribution, where extreme negative outliers pull averages downward despite most firms experiencing smaller abnormal returns.

Standard deviation (SD) was high, particularly in [-10,10] (0.134 for CAPM, 0.127 for 5FF). Minimum CAARs dropped to -0.702, while some firms saw gains up to 0.592. 5FF produced fewer negative CAARs than CAPM, likely because additional risk factors absorb some negative abnormal returns. Standard errors (SE) remained low, ensuring precise estimates despite firm-level variability.

T-statistics confirm statistical significance. CAPM reports highly negative values (-11.5 to -13.0), while 5FF ranges from -2.0 to -10.0, reinforcing that abnormal returns significantly differ from zero. Low SE(Mean), due to a large sample size (7,976 observations), further enhances precision. The higher absolute T-statistics in CAPM suggest that 5FF accounts for additional risk factors, weakening significance slightly, yet both models confirm a strong stock market reaction.

To mitigate the influence of extreme values, I winsorize my independent and control variables at the 1st and 99th percentiles. This ensures that outliers do not excessively distort the regression estimates while preserving the overall distribution of the data.

Summary Statistics

	Mean	Median	SD	Min	Max	p25	p75	SE (mean)	T-stat
CAPM CAAR [-5,10]	-0,012	-0,009	0,117	-0,701	0,442	-0,07	0,052	0,001	-9,160
CAPM CAAR [-10,10]	-0,023	-0,017	0,134	-0,702	0,442	-0,092	0,053	0,002	-15,329
CAPM CAAR [-5,5]	-0,013	-0,01	0,093	-0,47	0,366	-0,06	0,038	0,001	-12,484
5FF CAAR [-5,10]	-0,002	0,001	0,119	-0,692	0,592	-0,058	0,06	0,001	-1,501
5FF CAAR [-10,10]	-0,01	-0,006	0,127	-0,542	0,428	-0,074	0,061	0,001	-7,032
5FF CAAR [-5,5]	-0,009	-0,004	0,092	-0,445	0,357	-0,056	0,043	0,001	-8,737
Total Assets	15,529	15,263	1,983	9,667	22,529	14,136	16,747	0,019	833,558
Total Debt / Common Equity	36,804	10,62	71,146	-124,38	584,36	0,3	41,43	0,672	54,778
Current Ratio	3,456	2,42	3,406	0,23	34,61	1,61	3,92	0,032	107,891
Return on Equity	5,837	8,07	23,681	-199,73	66,85	2,38	15,18	0,232	25,154
ESG Score	3,746	3,901	0,56	2,194	4,483	3,339	4,215	0,015	252,426
CO_2 Emissions	12,526	13,019	1,729	5,948	16,267	11,539	13,758	0,060	207,961
Observations	12181								

Table 2- Summary Statistics Complete Dataset

3.1.2. Fama-French

Expected returns were computed using both the CAPM and the 5FF model to ensure robustness. CAPM only accounts for market risk, potentially leaving out significant factors that affect stock returns, while 5FF incorporates firm-specific characteristics that explain return fluctuations over time.

The five factors—market, size (SMB), value (HML), profitability (RMW), and investment (CMA)—were extracted from the Kenneth French database in addition to the risk-free rate. In empirical finance research, methodological consistency is ensured by this frequently used dataset.

3.1.3 Climate Events

The extreme weather event data, including storms and floods, were gathered from the EM-DAT [6]International Disaster Database, managed by the Centre of Research on the Epidemiology of Disasters (CRED) at the University of Louvain.

EM-DAT records disasters exceeding local response capacity, requiring external assistance, and supports humanitarian efforts, risk assessment, and disaster preparedness.

For this platform to record human and economic losses for disasters, at the country level, it needs to fulfil at least one of the following criteria:

- 10 fatalities;

[6] EM-DAT tracks over 22,000 large-scale disasters worldwide from 1900 onward, sourcing data from UN agencies, NGOs, insurers, research institutions, and media.

- 100 affected people;
- a declaration of state of emergency;
- a call for international assistance.

EM-DAT categorizes disasters as Natural (Hydrological, Meteorological, Geophysical, Biological, and Climatological) or Technological (Transport, Industrial, Miscellaneous). This study focuses on Natural events—specifically storms and floods, the most common hazards in the database.

A total of 30 events (10 per country) were selected based on economic and human impact. Only country-specific companies were analyzed for weather events in their respective regions. The following table summarizes the key event data.

3.1.4 Independent Variables

This study examines the ESG Score and CO_2 Emissions as key independent variables to assess financial market reactions to climate-related events. The primary hypothesis tests whether higher ESG scores lead to more favourable CAARs, indicating investor confidence in sustainable firms, while higher CO_2 emissions may correlate with lower CAARs, reflecting regulatory risks and reputational damage.

To ensure robustness, the ESG Score and CO_2 Emissions are tested separately. ESG is analysed independently to assess its impact on market reactions, while CO_2 Emissions are examined separately to determine whether firms with higher carbon footprints experience systematically worse stock performance after climate events.

Both variables' data was sourced from LSEG Workspace.

3.1.4.1 ESG Score

The ESG Score from LSEG Workspace measures corporate sustainability performance, ensuring comparability across industries and regions. It follows a five-step methodology incorporating company-reported data and external sources for reliability. [7]

[7] LSEG operates one of the world's largest ESG data collection networks, with 700+ analysts processing data from public sources like annual reports, sustainability disclosures, and stock exchange filings. A strict quality assurance process—including 400 error checks, 300 automated screenings, and frequent audits—ensures data accuracy, consistency, and comparability across industries.

1. ESG Category Scores: Built on 10 ESG categories (e.g., carbon emissions, human rights) assessed through 186 standardized data points. Companies are ranked relative to industry peers for Environmental and Social factors and country peers for Governance.
2. Materiality Weightings: Industry-specific weightings ensure relevance. Carbon emissions, for instance, are more critical for heavy industries than services. This step ensures that the ESG Score places greater emphasis on the ESG aspects that are most material to a company's sector.
3. ESG Score Aggregation: Once the ten category scores have been calculated and weighted, they are aggregated into an overall ESG Score. Category scores are weighted and aggregated into a percentile ranking (0–100%) and letter grades, D- (poor performance) to A+ (leading performance)
4. Controversy Integration: To address the limitations of company-reported ESG data, LSEG incorporates external data (e.g., news, regulatory filings) that adjusts scores based on 23 controversy topics, with scaling factors to prevent large firms from being unfairly penalized:
   - Large-cap companies: Controversies are weighted one-third as heavily.
   - Mid-cap companies: Controversies are weighted at 0.67.
   - Small-cap companies: No adjustments are made.
5. Final ESG Score: This integrated score reflects both a company's ESG performance and any ESG-related controversies. Companies that face major ESG-related controversies see their final ESGC score adjusted downward, making this metric a more comprehensive measure of corporate sustainability.

For this study, the logarithm of ESG Score is used to normalize skewed data and improve regression analysis. The Environmental, Social, and Governance pillars are analysed separately, with Environmental expected to have the strongest impact on CAARs due to its direct link to climate risk.

The dataset shows an ESG Score mean of 3.746 and a median of 3.901, with low dispersion (SD = 0.56) and a range of 2.194 to 4.483, indicating moderate sustainability performance across firms. However, only 1,424 observations are available for ESG data, highlighting reporting limitations that may influence findings, as firms disclosing ESG metrics may already prioritize sustainability.

3.1.4.2 CO_2 Emissions

Understanding a company's carbon footprint is essential for assessing its environmental impact and exposure to climate-related risks.

LSEG employs a hierarchical, multi-model approach to gather and estimate CO_2 emissions data, ensuring accuracy and transparency. The process involves:

As-Reported Climate Data: This dataset is derived from publicly available disclosures, including annual reports and sustainability filings. It involves a set of 380 climate-related measures, systematically collected since 2002. These measures provide insights into companies' environmental performance, regulatory compliance, and sustainability initiatives.

Estimated Emissions (Scope 1, 2, 3): Used when companies do not disclose data:

- Scope 1: Direct emissions from owned/controlled sources.
- Scope 2: Indirect emissions from purchased electricity, heating, cooling.
- Scope 3: Indirect emissions across the value chain.

The estimation models for missing data used by LSEG are:

- CO_2 Model: Estimates emissions based on the latest available data, normalized by factors such as the number of employees and net sales.
- Energy Model: Uses data on total energy consumed or produced, applying industry-specific emission factors to estimate CO_2 emissions.
- Median Model: In cases where other models are inapplicable, this model uses median emissions data from peer companies within the same industry to estimate a company's emissions.

For this study, logarithmic CO_2 Emissions are used, normalizing extreme values and allowing for percentage-based interpretation.

The dataset shows a mean log CO_2 Emissions of 2.713 (median 2.739, SD 0.512), indicating moderate carbon footprints. However, only 824 observations are available, reflecting limited emission disclosures among tech firms, suggesting environmental concerns are not yet a priority for all in Asia.

3.1.5 Control Variables

The control variables, sourced from LSEG Workspace, capture key aspects of financial health. Total Assets (log-transformed) represent firm size and resilience to shocks, with a mean of

15.529, median of 15.263, and SD of 1.983, suggesting a relatively symmetrical distribution. The range (9.667 to 22.529) includes both small and large firms. Total Debt to Common Equity measures financial leverage, with a mean of 36.804 and a high SD of 71.146, indicating significant variation in firms' reliance on debt financing. Current Ratio, a measure of liquidity, has a mean of 3.456 and median of 2.42, though its high SD of 3.406 and maximum value of 34.61 suggest that while most firms maintain liquidity, some have extremely high ratios. Return on Equity (ROE), which reflects profitability, has a mean of 5.837, but with substantial variability (SD 23.681, range -199.73 to 66.85), showing that while some firms are highly profitable, others are experiencing severe financial losses.

3.2 Event Window

To conduct the event study, we define an event window, the period surrounding the extreme weather event where abnormal stock performance is analyzed. This study uses three event windows to capture both immediate and longer-term effects:

a. [-5, 10]: Captures short-term anticipation and extended post-event adjustments, ideal for detecting immediate and medium-term responses.
b. [-10, 10]: Provides a broader view, including long-term speculation before the event and persistent effects afterward.
c. [-5, 5]: Focuses on immediate market reactions, minimizing interference from unrelated macroeconomic shocks.

Not analysing any days prior to the event was considered as we are not studying events that might involve insider trading or information that might be exposed, but I found it important to include at least 5 days prior to also analyse potential anticipatory effects. Particularly, climate disasters such as floods and storms have increased predictability due to meteorological advances, satellite monitoring, and early warning systems. Including days before the event allows for an assessment of whether the market incorporates these predictive signals into stock prices.

3.3 Estimation Period

The estimation period spans 250 trading days, providing sufficient data to estimate expected returns under normal market conditions. If the event day is not a trading day, the estimation period starts from the last trading day before the event, ensuring data consistency. This approach maintains the integrity of the analysis, offering a reliable basis for comparing observed and expected returns to calculate abnormal returns during the event window.

3.4 Stock Returns and Expected Returns

For each company, daily stock returns were calculated using the following formula:

$$(1)\ R_{it} = \frac{P_{it} - P_{it}\text{-}1}{P_{it}\text{-}1}$$

Where *R*it represents the return for company i on day t, and *P*it and *P*it-1 are the closing prices of the stock on days t and t-1, respectively.

Before estimating expected returns, I segmented the dataset by region, ensuring analysis focused only on companies in the affected area. This approach recognizes that natural disasters primarily impact local markets, where news and investor attention are most concentrated.

To calculate the expected returns, we employed the Capital Asset Pricing Model (CAPM):

$$(2)\ E(R_{it}) = \alpha + \beta^{*} R_m + \varepsilon_{it}$$

Where R_m is the market return, and β represents the sensitivity of the individual company's stock to the overall market. The CAPM was applied over the estimation period, which spans 250 trading days before each event, avoiding interference from other overlapping extreme weather events.

To improve the robustness of our expected returns estimation, we also applied the Fama-French Five-Factor (5FF) model. The 5FF model incorporates five factors: market return, size (SMB, small minus big), value (HML, high minus low), profitability (RMW, robust minus weak), and investment (CMA, conservative minus aggressive).

$$(3)\ R_{it} - R_{Ft} = \alpha_i + \beta_i\left(R_{m_t} - R_{Ft}\right) + s_i SMB + h_i HML + r_i RMW + c_i CMA + \varepsilon_{it}$$

This model provides a more comprehensive view of the drivers behind stock returns, particularly for diverse portfolios or sectors such as technology. The inclusion of the 5FF model allows us to validate our results across multiple frameworks used for a robustness test.

3.5 Abnormal Returns and Cumulative Abnormal Returns

Abnormal returns (AR) were calculated as the difference between the observed stock returns and the expected returns derived from the CAPM model during the defined event window:

$$(4)\ AR_{it} = R_{it} - E(R_{it})$$

To capture both the short-term and medium-term effects of extreme weather events, the analysis used the three distinct event windows.

Cumulative abnormal returns (CAR) were then derived by summing the abnormal returns throughout the event window for each one of the 30 events (10 for Asiatic country):

$$(5)\ CAR_i(t_1, t_2) = \sum_{t=t_1}^{t_2} AR_{it}$$

In simpler terms, t_1 and t_2 define the beginning and end of the event window, respectively. So, in the event window [-10, 10], t_1=−10 would indicate 10 days before the event, and t_2=10 would refer to 10 days after the event.

3.6 Regression Analysis

To complement the event study, a progressive regression framework was employed to identify the key drivers behind the abnormal returns during extreme weather events. The dependent variable is CAARs for each firm and event window.

Panel regressions were conducted in two sets, using ESG Score and its components in one, and CO_2 emissions and its components in the other. Control variables—Size, Leverage, Liquidity, and Performance—were progressively incorporated to assess both their direct impact and interaction with the independent variables.

This analysis provides key insights into the factors influencing market reactions to climate-induced shocks in the Asian technology sector.

4. Results

This section discusses the results of the event study analysing the impact of storm and flood events on the stock performance of technology firms across Japan, China, and South Korea. Firstly, we conduct an analysis of the Daily Average Abnormal Returns, secondly, the Hausman Test is executed in order to select the most appropriate model for the regressions and lastly, we perform a detailed examination of the empirical findings of the regressions.

4.1 Daily Average Abnormal Return

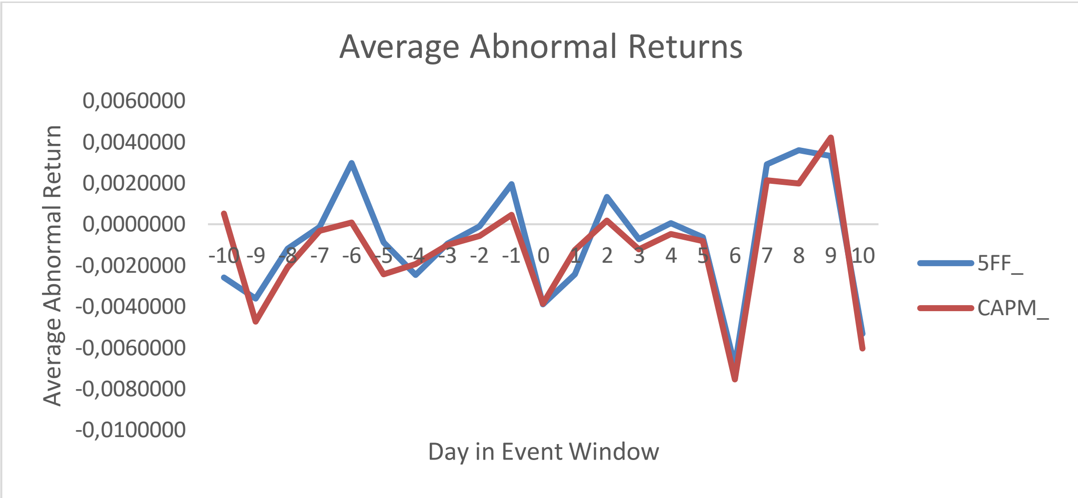

Figure 1- Daily Average of Abnormal Returns

This graph represents the Daily Average Abnormal Returns (AAR) everyday within our longest event window: [-10,10], allowing us to analyse whether the disaster effect is felt before [-10,-10], in the moment of the event [0] or after [1,10]. We also identify which of the event windows exhibit stronger effects, market adjustment periods, distinguishing immediate shocks, prolonged reactions, or potential recovery effects. To test robustness and examine factors like firm size and profitability, we use both CAPM and 5FF models.

The x-axis represents event days (where 0 marks the event), while the y-axis shows daily AAR. Positive values indicate AR above expectations, while negative values suggest underperformance.

Before the event, [-10, -10], the AAR exhibits significative volatility, but no pattern behaviour and it rounds the 0 line: which might indicate that investors don't have previous information on these disasters. We're able to observe an immediate effect on the day of the event: there's an instantaneous fall to -0.004 on both models, which might indicate the market's initial and quick negative reaction to the impact of the natural disaster, possibly explained by panic selling or uncertainty regarding the impacts of the event.

Before the event ([-10,-1]), AAR fluctuates around zero without a clear pattern, suggesting no prior investor knowledge of the disaster. On the event day (0), there is an immediate drop to -0.004 in both models, likely driven by panic selling or uncertainty. However, instead of a sustained decline, volatility persists, indicating uncertain market signals until day 6, when AAR reaches its lowest point (-0.0078), followed by a strong rebound on day 9 (0.004). This suggests that investors took time to fully assess financial consequences, factoring in government intervention, supply chain disruptions, and corporate resilience.

On day 10, AAR falls to nearly -0.008, implying that the day 9 recover was mometary, possibly due to profit-taking or reevaluation of long-term risks. Alternatively, the volatility could be market noise, suggesting that the technology sector does not view such disasters as fundamentally disruptive—perhaps because tech firms face lower physical asset exposure compared to manufacturing or infrastructure industries.

4.2 Hausman Test

There are two main models for panel-data regressions: fixed effects (FE) and random effects (RE). The RE model assumes individual effects are uncorrelated with regressors, while the FE model accounts for potential correlation. Choosing between them depends on whether firm-specific effects in CAARs correlate with control variables. To assess this, we use the Hausman test (Hausman, 1978), which evaluates whether the RE model provides consistent estimates compared to FE.

The key difference lies in handling unobserved heterogeneity. The FE model controls for omitted variable bias by assuming correlation between individual effects and explanatory variables but cannot estimate time-invariant variables (Baltagi & H., 2005). The RE model, assuming no such correlation, allows for their estimation but risks bias if the assumption is false.

The Hausman test helps determine which assumption holds by testing the null hypothesis:

H_0:Random Effects (RE) is the appropriate model (no correlation between firm-specific effects and explanatory variables)

H_1: Fixed Effects (FE) is the appropriate model (correlation exists)

The Hausman statistic is computed as follows:

$$(6)\ x^2 = (\beta_{FE} - \beta_{RE})^T [VAR(\beta_{FE}) - VAR(\beta_{RE})]^{-1} (\beta_{FE} - \beta_{RE})$$

where:

β_{FE} and β_{RE} are the coefficient estimators for each model.

$VAR(\beta_{FE})\ and\ VAR(\beta_{RE})$ refer to the covariance matrices of the estimators.

The result of this test is compared to the critical value computed from the chi-squared distribution. The number of degrees of freedom used in the test depends on the number of parameters being tested. A low chi-square value and a high p-value imply that both models provide similar estimates, meaning that the RE model is more appropriate due to its efficiency in estimating time-invariant variables (Greene, 2012).

		Chi-square test value	P-value	**Conclusion**
ESG	CAPM CAAR [-5,10]	1,65	0,8956	Fail to Reject H0
	5FF CAAR [-5,10]	2,95	0,7072	
CO_2	CAPM CAAR [-5,10]	4,84	0,4352	
	5FF CAAR [-5,10]	6,46	0,2637	
ESG	CAPM CAAR [-10,10]	1,44	0,9204	
	5FF CAAR [-10,10]	4,36	0,4986	
CO_2	CAPM CAAR [-10,10]	5,76	0,3305	
	5FF CAAR [-10,10]	8,94	0,1113	
ESG	CAPM CAAR [-5,5]	1,54	0,908	
	5FF CAAR [-5,5]	4,06	0,5407	
CO_2	CAPM CAAR [-5,5]	5,43	0,3659	
	5FF CAAR [-5,5]	5,66	0,3408	

Table 3- Hausman Test

The results for the Hausman Test are displayed on Table 3. The test was conducted separately for ESG and CO_2 regressions, applying both the CAPM and Fama-French Five-Factor (5FF) models across three event windows: [−5,10], [−10,10], and [−5,5].

Across all regressions, the chi-square test values remain relatively low, and the p-values exceed significance thresholds (0.05 and 0.10). The highest chi-square statistic is 8.94 (for the 5FF model of CO_2 in the [−10,10] window), but even this result does not reach statistical significance at the 5% level, with a p-value of 0.1113. The other test statistic values remain even lower, with p-values consistently above 0.3, indicating that the differences between the FE and RE estimates are not statistically significant.

Thus, we fail to reject the null hypothesis, suggesting no strong correlation between firm-specific effects and explanatory variables. Consequently, the Random Effects (RE) model is the most appropriate, aligning with prior research, such as (Petersen, 2008), which finds that RE models often provide more efficient estimates in firm-level event studies unless strong endogeneity concerns exist.

The lack of significance in the Hausman test suggests that ESG and CO_2 effects on CAARs do not strongly depend on firm-specific unobserved characteristics.

4.3 Heteroskedasticity and Serial Correlation

Having selected the random effects model, I also need to ensure that my data is not affected by heteroskedasticity or serial correlation, which could interfere with standard errors and lead to unreliable conclusions. To address this, I apply the Huber-White-Sandwich estimator using the "vce(robust)" command in all regressions. This adjustment provides robust standard errors, ensuring their validity regardless of underlying heteroskedasticity or correlation within observations. Additionally, I log-transform my independent variables to mitigate potential heteroskedasticity and improve the linearity of relationships in the model.

4.4 Regression Results

In this section, I present the regression results examining the impact of ESG Score and CO_2 Emissions on CAAR, controlling for various firm-level variables previously discussed.

4.4.1. ESG and Components

Results indicate that ESG Score has a weakly significant positive effect on CAARs at the 5% level in some CAPM specifications. In models (2) and (3), ESG coefficients are 0.021 ($p < 0.1$) and 0.02 ($p < 0.1$), suggesting a one-unit ESG increase is linked to a 2.1% and 2.0% rise in CAARs. This implies investors may reward firms with higher ESG ratings post-event, potentially for their sustainable practices. However, in 5FF models, ESG coefficients (0.013 to 0.006) are insignificant, indicating that controlling for additional risk factors weakens ESG's explanatory power.

Total Assets consistently show negative coefficients (-0.003 to -0.001, SE = 0.003) but lack significance. While larger firms are typically perceived as less risky, this aligns with (Azizi et al, 2023), which suggests that greater media exposure and investor scrutiny may amplify negative abnormal returns post-disaster.

Quick Ratio, Total Debt/Common Equity, and ROE are largely insignificant across models. CAPM coefficients range from -0.001 to 0.00019, and 5FF shows similar results (-0.002 to 0.001). This suggests that traditional financial ratios lose explanatory power in disaster-induced market volatility. Investors may prioritize other factors, contrasting with (Acharya et al. , 2011) but aligning with (Fama & French, 1992), which finds firm size more relevant than leverage—consistent with our findings.

The Social Pillar is significant in CAPM (model 8) with a coefficient of 0.015 ($p < 0.05$), while Environmental and Governance Pillars remain insignificant (-0.002 to 0.002). This suggests investors favor firms with strong stakeholder engagement during disasters, but this effect disappears in 5FF, implying other risk factors outdoes social responsibility when broader controls are applied.

CAPM CAAR [-5,10]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESG Score	0.014	0.021*	0.02*	0.02*	0.02*			
	(0.009)	(0.011)	(0.011)	(0.011)	(0.011)			
Total Assets		-0.003	-0.003	-0.003	-0.003	-0.003	-0.001	-0.003
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Quick Ratio			-0.0001	-0.0005	-0.001	-0.0003	-0.001	-0.0003
			(0.002)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)
Total Debt / Common Equity				-0.00004	-0.00003	0.00003	-0.00004	-0.00002
				(0.0001)	(0.0001)	(0.00008)	(0.00008)	(0.00008)
Return On Equity					0.00014	0.00004	0.00014	0.00019
					(0.0003)	(0.0003)	(0.0003)	(0.0003)
Environmental Pillar						0.002		
						(0.004)		
Governance Pillar							0.002	
							(0.009)	
Social Pillar								0.015**
								(0.007)
Constant	-0.056*	-0.016	-0.013	-0.012	-0.01	0.068	0.011	0.005
	(0.032)	(0.048)	(0.051)	(0.051)	(0.052)	(0.046)	(0.055)	(0.049)
Observations	834	707	706	706	706	562	706	706
Overall R^2	0.0029	0.0094	0.0093	0.0097	0.01	0.0083	0.0025	0.0121

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 4- ESG Progressive Regressions CAPM [-5,10]

5FF CAAR [-5,10]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESG Score	0.013	0.008	0.007	0.006	0.006			
	(0.009)	(0.012)	(0.012)	(0.012)	(0.012)			
Total Assets		0.003	0.003	0.003	0.003	0.003	0.003	0.003
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Quick Ratio			-0.001	-0.002	-0.002	0.001	-0.002	-0.002
			(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)
Total Debt / Common Equity				-0.0012	-0.00004	0.00003	-0.00004	-0.00004
				(0.00007)	(0.00008)	(0.00008)	(0.00008)	(0.00008)
Return On Equity					0.0001	-0.00007	0.0001	0.0001
					(0.0003)	(0.0003)	(0.0003)	(0.0003)
Environmental Pillar						-0.002		
						(0.005)		
Governance Pillar							0.004	
							(0.01)	
Social Pillar								0.024
								(0.007)
Constant	-0.06*	-0.093*	-0.084	-0.082	-0.08	-0.056	-0.082	-0.073
	(0.033)	(0.052)	(0.055)	(0.055)	(0.056)	(0.051)	(0.059)	(0.054)
Observations	834	707	706	706	706	562	706	706
Overall R-squared	0.0053	0.0064	0.0061	0.0067	0.0069	0.0014	0.0062	0.0059

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 5- ESG Progressive Regressions 5FF [-5,10]

The next two tables show the results regarding our longest time window [-10,10], where findings remain very similar to what we observed in the previous time window.

In the CAPM model, the ESG Score is significant at the 10% level ($p < 0.1$) in models (2)–(5), with a 0.021 coefficient, indicating a small positive impact on CAARs. However, in the 5FF model (Table 5), ESG Score is not significant, with coefficients between 0.002 and 0.008. This suggests that while higher ESG Scores may boost CAARs in CAPM, they lose significance in 5FF, implying that additional risk factors diminish ESG's influence on stock reactions.

Total Assets (Table 4) show a highly significant negative effect ($p < 0.01$) in models (2)–(6) and (8), with a coefficient of -0.009, and remain significant at $p < 0.05$ (-0.006) in model (7). In 5FF, coefficients remain negative but lose significance (-0.004 to -0.002). This supports the idea that larger firms face stronger negative abnormal returns after extreme events, suggesting that size amplifies market reactions to climate risks rather than buffering them, aligning with (Fama & French, 1992).

The Quick Ratio, D/E ratio, and ROE remain insignificant, reinforcing that investors may not prioritize traditional financial metrics when reacting to climate shocks.

For ESG sub-pillars, results mirror previous findings. The Social Pillar is even more significant ($p < 0.01$) in CAPM (model 8), with a coefficient of 0.019, supporting a positive relationship between social responsibility and CAARs. Meanwhile, the Environmental and Governance Pillars remain insignificant in both models.

CAPM CAAR [-10,10]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESG Score	0.005	0.021*	0.021*	0.021*	0.021*			
	(0.009)	(0.011)	(0.012)	(0.012)	(0.012)			
Total Assets		-0.009***	-0.009***	-0.009***	-0.009***	-0.009***	-0.006**	-0.01***
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Quick Ratio			-0.0005	-0.0003	-0.0003	-0.0004	-0.001	0.00009
			(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Total Debt / Common Equity				0.00002	0.00003	0.00009	0.00002	0.000043
				(0.00008)	(0.00008)	(0.0001)	(0.00008)	(0.00008)
Return On Equity					0.00014	0.0003	0.0002	0.0002
					(0.0003)	(0.0003)	(0.0003)	(0.0003)
Environmental Pillar						0.001		
						(0.005)		
Governance Pillar							0.00001	
							(0.01)	
Social Pillar								0.019***
								(0.007)
Constant	-0.021	0-082*	0.086*	0.085	0.086*	0.149***	0.113**	0.1**
	(0.033)	(0.048)	(0.052)	(0.052)	(0.052)	(0.056)	(0.056)	(0.05)
Observations	834	707	706	706	706	562	706	706
Overall R-squared	0.0003	0.0268	0.0269	0.0270	0.0274	0.0335	0.0188	0.0345

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 6- ESG Progressive Regressions CAPM [-10,10]

5FF CAAR [-10,10]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESG Score	0.002	0.007	0.007	0.008	0.008			
	(0.009)	(0.012)	(0.012)	(0.012)	(0.012)			
Total Assets		-0.003	-0.003	-0.003	-0.003	-0.004	-0.002	-0.003
		(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)
Quick Ratio			0.001	0.001	0.0004	0.001	0.0002	0.001
			(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Total Debt / Common Equity				0.00001	0.00004	0.00009	0.00004	0.0001
				(0.00008)	(0.00008)	(0.00009)	(0.00008)	(0.00008)
Return On Equity					0.0003	0.0004	0.0003	0.0003
					(0.0003)	(0.0003)	(0.0003)	(0.0003)
Environmental Pillar						-0.002		
						(0.005)		
Governance Pillar							0.001	
							(0.01)	
Social Pillar								0.006
								(0.007)
Constant	-0.011	0.015	0.012	0.011	0.016	0.06	0.023	0.021
	(0.033)	(0.051)	(0.054)	(0.054)	(0.055)	(0.058)	(0.058)	(0.053)
Observations	834	707	706	706	706	562	706	706
Overall R-squared	0.0004	0.0056	0.0058	0.006	0.0073	0.0113	0.0045	0.078

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 7- ESG Progressive Regressions 5FF [-10,10]

The following tables present the findings for the progressive regressions we performed for the shortest time window [-5,5].

In this window, ESG Score loses statistical significance seen in previous windows but maintains a positive impact. Total Assets still show a weak negative effect, implying larger firms face slightly stronger negative market reactions in the short term, though less pronounced than in longer windows.

The Quick Ratio and D/E Ratio continue to be insignificant with coefficients rounding from -0.001 to 0.00007.

A key difference in this timeframe is that ROE gains significance in models (5), (7), and (8). Unlike previous findings, firms with higher profitability experience slightly more positive abnormal returns immediately after the event. ROE coefficients range from 0.0004 to 0.001, reaching 5% significance in some 5FF specifications, suggesting that profitability plays a minor but notable role in short-term investor sentiment. This contrasts with the [-10,10] and [-5,10] windows, where ROE was consistently insignificant, indicating that investors initially favor profitable firms post-event before size and ESG performance become more dominant over time.

ESG Sub-Pillars follow previous trends. The Social Pillar is weaker ($p < 0.1$) in CAPM (model 8), with a coefficient of 0.01, maintaining a positive relationship with CAARs. Environmental and Governance Pillars remain insignificant in both CAPM and 5FF.

CAPM CAAR [-5,5]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESG Score	0.007	0.012	0.011	0.011	0.011			
	(0.008)	(0.01)	(0.009)	(0.01)	(0.009)			
Total Assets		-0.004	-0.004*	0.004*	-0.005*	-0.004*	-0.003	-0.005**
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)
Quick Ratio			-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
			(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Total Debt / Common Equity				0.00001	0.00005	0.00007	0.00004	0.00006
				(0.00007)	(0.00007)	(0.00007)	(0.00007)	(0.00007)
Return On Equity					0.0004*	0.0003	0.0004*	0.0004*
					(0.0002)	(0.0003)	(0.0002)	(0.0002)
Environmental Pillar						-0.001		
						(0.004)		
Governance Pillar							-0.003	
							(0.008)	
Social Pillar								0.01*
								(0.005)
Constant	-0.03	0.022	0.036	0.035	0.041	0.074*	0.063	0.048
	(0.028)	(0.041)	(0.043)	(0.043)	(0.043)	(0.044)	(0.045)	(0.041)
Observations	834	707	706	706	706	562	706	706
Overall R-squared	0.0005	0.0099	0.011	0.0112	0.0168	0.0187	0.014	0.0207

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 8- ESG Progressive Regressions CAPM [-5,5]

5FF CAAR [-5,5]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESG Score	0.01	0.006	0.005	0.005	0.005			
	(0.007)	(0.009)	(0.009)	(0.009)	(0.009)			
Total Assets		0.002	0.002	0.002	0.001	0.001	0.002	0.001
		(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)
Quick Ratio			-0.0002	-0.0003	-0.001	-0.001	-0.001	-0.0004
			(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Total Debt / Common Equity				-6.16e-06	0.00004	0.0001	0.00003	0.00004
				(0.0001)	(0.00006)	(0.00007)	(0.00006)	(0.00006)
Return On Equity					0.001**	0.0003	0.001**	0.001**
					(0.0002)	(0.0003)	(0.0002)	(0.0002)
Environmental Pillar						-0.001		
						(0.004)		
Governance Pillar							-0.003	
							(0.008)	
Social Pillar								0.004
								(0.005)
Constant	-0.049*	-0.066	-0.059	-0.059	-0.052	-0.034	-0.039	-0.048
	(0.026)	(0.04)	(0.042)	(0.042)	(0.042)	(0.044)	(0.044)	(0.041)
Observations	834	707	706	706	706	562	706	706
Overall R-squared	0.0041	0.0038	0.0033	0.0032	0.0106	0.0018	0.009	0.0107

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 9- ESG Progressive Regressions 5FF [-5,5]

4.4.2. CO_2 and Components

This section examines progressive regressions where CO_2 Total Emissions is the independent variable, assessing whether CO_2 emissions impact stock price reactions after extreme weather events.

CO_2 Total Emissions remains insignificant across all models in CAPM and 5FF, with coefficients between 0.002 and 0.004, suggesting investors do not react significantly to a firm's overall CO_2 emissions in short-term stock movements post-event.

In CAPM, Total Assets is significantly negative ($p < 0.01$) in model (8), with a coefficient of -0.011, while in other models, it remains negative but not consistently significant. In 5FF, it is weakly significant ($p < 0.1$) in model (8), with a coefficient of -0.007, reinforcing prior findings that larger firms experience stronger negative abnormal returns.

Liquidity (Quick Ratio), leverage (D/E ratio), and profitability (ROE) remain insignificant, aligning with Broadstock et al. (2021) and Krüger (2015), who argue that short-term stock price reactions are driven more by external risk factors (e.g., environmental exposure, market sentiment) than firm-level financial ratios

CO_2 Direct and Indirect Emissions are insignificant, but Scope 3 Indirect Emissions are highly significant ($p < 0.01$) in both CAPM (model 8, coefficient -0.008) and 5FF (model 8, coefficient -0.009). The strong negative association suggests firms with higher supply chain emissions face greater investor backlash due to regulatory and reputational risks, supporting Chava (2014). As Scope 3 emissions are harder to control, firms with higher values may be perceived as less prepared for climate risks, reinforcing the growing importance of supply chain sustainability disclosures in investment decisions.

CAPM CAAR [-5,10]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CO2 Total Emissions	0.002 (0.003)	0.003 (0.003)	0.002 (0.003)	0.002 (0.003)	0.002 (0.003)			
Total Assets		-0.005 (0.003)	-0.005 (0.003)	-0.005 (0.003)	-0.005 (0.003)	-0.004 (0.003)	-0.005 (0.003)	-.011*** (0.004)
Quick Ratio			-0.002 (0.004)	-0.003 (0.004)	-0.003 (0.004)	-0.002 (0.005)	-0.001 (0.004)	0.003 (0.007)
Total Debt / Common Equity				-.00007 (0.00008)	-.00007 (0.0001)	-.00002 (0.0001)	-.00002 (0.0001)	-.00002 (0.0001)
Return On Equity					0.00006 (0.0004)	-0.001 (0.001)	-0.0001 (0.001)	-0.001 (0.001)
CO2 Direct Emissions						-0.002 (0.002)		
CO2 Indirect Emissions							0.003 (0.004)	
CO2 Indirect Emissions Scope 3								-.008*** (0.003)
Constant	-0.02 (0.031)	0.075 (0.061)	0.08 (0.063)	0.083 (0.064)	0.082 (0.065)	0.123** (0.061)	0.064 (0.068)	0.345*** (0.08)
Observations	440	331	331	331	331	265	274	195
Overall R-squared	0.001	0.0132	0.0132	0.015	0.015	0.0259	0.017	0.1163

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 10- CO_2 Progressive Regressions CAPM [-5,10]

5FF CAAR [-5,10]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CO2 Total Emissions	0.003	0.004	0.003	0.003	0.003			
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)			
Total Assets		-0.001	-0.001	-0.001	-0.001	-0.0004	-0.001	-0.007*
		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Total Debt / Common Equity				-.00004	-.00002	-0.0002	-0.001	-0.0002
				(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Return On Equity					0.0002	-0.001	-0.001	-0.001
					(0.0004)	(0.001)	(0.001)	(0.001)
CO2 Direct Emissions						0.00002		
						(0.003)		
CO2 Indirect Emissions							0.003	
							(0.005)	
CO2 Indirect Emissions Scope 3								-.009***
								(0.003)
Constant	-0.036	-0.029	-0.021	-0.02	-0.02	0.03	-0.025	0.285***
	(0.034)	(0.072)	(0.074)	(0.075)	(0.076)	(0.081)	(0.083)	(0.084)
Observations	440	331	331	331	331	265	274	195
Overall R-squared	0.0025	0.0044	0.0046	0.0051	0.0062	0.009	0.0087	0.0839

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 11- CO_2 Progressive Regressions 5FF [-5,10]

In the [-10,10] window, CO_2 Total Emissions becomes weakly significant ($p < 0.1$) in CAPM (models 2 and 3), whereas in [-5,10], it remained insignificant. This suggests that including five additional pre-event days increases investor attention to total emissions. However, as immediate reactions take place, Scope 3 emissions gain importance, making Total CO_2 Emissions less relevant post-event.

Findings on Total Assets remain consistently significant and negative across models, while Quick Ratio, D/E, and ROE remain insignificant, consistent with previous time windows.

For CO_2 components, CO_2 Indirect Emissions becomes significant ($p < 0.05$, 0.011, model 6) in [-10,10], unlike in [-5,10], where they were insignificant. Scope 3 Indirect Emissions also remain significant in CAPM. While their negative coefficients support the assumption that higher CO_2 emissions negatively impact CAARs, the positive coefficient on Indirect Emissions may indicate that purchased energy reflects firm size and energy dependence rather than direct climate risk exposure.

CAPM CAAR [-10,10]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CO2 Total Emissions	0.003	0.007*	0.007*	0.007*	0.007			
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)			
Total Assets		-.011***	-.011**	-.011**	-.011**	-.01**	-.011**	-.017***
		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)
Quick Ratio			0.0001	0.0002	0.0003	0.0002	0.002	0.008
			(0.005)	(0.005)	(0.005)	(0.007)	(0.006)	(0.007)
Total Debt / Common Equity				7.32e-06	0.00002	-0.0002	-0.0002	-0.00006
				(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0001)
Return On Equity					0.0002	-0.0004	0.0001	-0.0007
					(0.0004)	(0.0006)	(0.001)	(0.0006)
CO2 Direct Emissions						-0.001		
						(0.003)		
CO2 Indirect Emissions							0.011**	
							(0.005)	
CO2 Indirect Emissions Scope 3								-0.006**
								(0.003)
Constant	-0.042	0.124	0.124	0.123	0.124	0.213***	0.082	0.417***
	(0.038)	(0.076)	(0.079)	(0.079)	(0.08)	(0.081)	(0.092)	(0.084)
Observations	440	331	331	331	331	265	274	195
Overall R-squared	0.0024	0.0495	0.0495	0.0494	0.0506	0.0563	0.0622	0.1529

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 12- CO_2 Progressive Regressions CAPM [-10,10]

5FF CAAR [-10,10]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CO2 Total Emissions	0.002	0.006	0.005	0.005	0.005			
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)			
Total Assets		-0.007*	-0.007*	-0.007*	-0.008*	-0.008**	-0.008*	-0.014***
		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)
Quick Ratio			-0.002	-0.002	-0.001	-0.002	-0.001	0.004
			(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.007)
Total Debt / Common Equity				2.93e-06	0.00004	-0.0002	-0.0002	-0.0001
				(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0001)
Return On Equity					0.0004	-0.0002	0.0003	-0.001
					(0.0004)	(0.001)	(0.001)	(0.001)
CO2 Direct Emissions						-0.0001		
						(0.002)		
CO2 Indirect Emissions							0.008*	
							(0.005)	
CO2 Indirect Emissions Scope 3								-0.006**
								(0.003)
Constant	-0.03	0.076	0.082	0.082	0.084	0.168**	0.059	0.364***
	(0.035)	(0.075)	(0.077)	(0.078)	(0.077)	(0.072)	(0.087)	(0.088)
Observations	440	331	331	331	331	265	274	195
Overall R-squared	0.0013	0.0258	0.0255	0.0255	0.0304	0.0340	0.0358	0.1082

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 13- CO_2 Progressive Regressions 5FF [-10,10]

The next tables present the results for the [-5,5] time window.

As in [-5,10], CO_2 Total Emissions remain insignificant across both CAPM and 5FF, suggesting they do not strongly influence short-term investor reactions. This reinforces the idea that total emissions are not the primary driver of abnormal returns, with investors likely prioritizing specific metrics like Scope 3 emissions.

The negative relationship between firm size and CAARs persists, with significance at $p < 0.1$ or $p < 0.05$ in CAPM, consistent with [-5,10]. This supports the conclusion that larger firms face greater stock market pressure after extreme events, likely due to their higher visibility and exposure to systemic risks.

The highly significant negative coefficient for Scope 3 Emissions ($p < 0.01$) in both models aligns with [-5,10], reaffirming that investors penalize firms with high supply chain emissions in short-term market reactions.

CAPM CAAR [-5,5]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CO2 Total Emissions	0.002	0.004	0.002	0.003	0.002			
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)			
Total Assets		-0.006*	-0.005	-0.005	-0.006*	-0.004	-0.006	-0.006**
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)
Quick Ratio			-0.004	-0.005	-0.005	-0.006	-0.002	-0.003
			(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)
Total Debt / Common Equity				-0.00003	-9.07e-06	-0.0001	-0.00007	-0.0002*
				(0.00007)	(0.00008)	(0.0001)	(0.0001)	(0.00008)
Return On Equity					0.0002	-0.0002	0.0003	-0.0004
					(0.0003)	(0.001)	(0.0004)	(0.0004)
CO2 Direct Emissions						-0.002		
						(0.002)		
CO2 Indirect Emissions							0.005	
							(0.004)	
CO2 Indirect Emissions Scope 3								-0.007***
								(0.002)
Constant	-0.029	0.063	0.079	0.08	0.082	0.121*	0.048	0.229***
	(0.028)	(0.058)	(0.06)	(0.06)	(0.06)	(0.064)	(0.068)	(0.059)
Observations	440	331	331	331	331	265	274	195
Overall R-squared	0.0009	0.0216	0.0268	0.0274	0.0306	0.0385	0.0257	0.107

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 14- CO_2 Progressive Regressions CAPM [-5,5]

5FF CAAR [-5,5]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CO2 Total Emissions	0.002	0.002	0.001	0.002	0.001			
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)			
Total Assets		-0.002	-0.002	-0.002	-0.002	-0.001	-0.002	-0.004
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Quick Ratio			-0.004	-0.005	-0.004	-0.006	-0.002	-0.003
			(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)
Total Debt / Common Equity				-0.0001	-0.00002	-0.0001	-0.00008	-0.0001
				(0.00007)	(0.00007)	(0.0001)	(0.0001)	(0.0001)
Return On Equity					0.0003	0.00009	0.0003	-0.0001
					(0.0003)	(0.001)	(0.0004)	(0.001)
CO2 Direct Emissions						-0.001		
						(0.002)		
CO2 Indirect Emissions							0.004	
							(0.003)	
CO2 Indirect Emissions Scope 3								-0.007***
								(0.002)
Constant	-0.028	0.002	0.016	0.018	0.02	0.045	-0.005	0.186***
	(0.026)	(0.054)	(0.056)	(0.057)	(0.056)	(0.06)	(0.063)	(0.063)
Observations	440	331	331	331	331	273	274	195
Overall R-squared	0.0011	0.0035	0.0077	0.0089	0.0131	0.0131	0.0109	0.0688

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 15- CO_2 Progressive Regressions 5FF [-5,5]

R^2 values are consistently higher for CO_2 regressions than for ESG regressions across all event windows, suggesting that CO_2 emissions (particularly Scope 3) better explain CAARs than ESG scores. This difference is most pronounced in [-10,10], where CO_2 models exceed 0.15 (CAPM) and 0.10 (5FF), while ESG models remain below 0.04.

R^2 values increase with longer event windows for both CO_2 and ESG models, indicating that stock price reactions to environmental factors take time to materialize, improving explanatory power over extended periods. However, CO_2 variables maintain stronger explanatory power even in shorter windows, reinforcing their greater relevance to investor behavior.

4.4.3 Robustness Analysis: Controlling for Year-Fixed Effects

To ensure the robustness of our results, we re-estimate the regressions by including year-fixed effects to control for time-specific shocks that may influence CAARs independently of firm-level characteristics. By accounting for variations across different years, this approach helps isolate the impact of CO_2 emissions and ESG factors. In the following section, we compare these results to our baseline regressions to assess whether the inclusion of time controls significantly changes the estimated relationships.

4.4.3.1. ESG and components

The tables in this section present an example of the most significant changes in the regressions, for more time windows consult the Appendix.

In the baseline regression, ESG Score was weakly significant ($p < 0.1$) in some models, suggesting a modest link to CAARs. However, after introducing year-fixed effects, ESG loses all significance, indicating that its prior relevance was likely driven by year-specific trends rather than ESG factors themselves. This reinforces the idea that investor reactions to extreme weather events are not consistently influenced by ESG scores when macroeconomic conditions are controlled for.

Total Assets initially had a negative coefficient, implying larger firms faced lower CAARs post-climate events. With year-fixed effects, the coefficient turns positive but remains insignificant, suggesting that previous negative effects were partly due to market-wide trends disproportionately affecting larger firms. This aligns with findings from the 5FF model, where firm size was not a significant predictor of CAARs, unlike in CAPM.

Several other firm-level variables also shift toward more positive coefficients but remain insignificant, indicating that previous negative relationships in the baseline model may have reflected broader economic downturns rather than firm-specific weaknesses.

Regarding explanatory power, R^2 values increase, confirming that including year-fixed effects improves model fit by accounting for macroeconomic trends. This suggests that part of the variation in CAARs was previously due to time-specific market dynamics rather than firm-level ESG performance.

CAPM CAAR [-5,10]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CO2 Total Emissions	0,026	0,017	0,019	0,016	0,017			
	(0.021)	(0.023)	(0.023)	(0.023)	(0.023)			
Total Assets		0.025	0.026	0.029	0.028	0.026	0.031	0.027
		(0.019)	(0.019)	(0.019)	(0.019)	(0.025)	(0.019)	(0.019)
Quick Ratio			0.004	0.003	0.003	0.001	0.003	0.004
			(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Total Debt / Common Equity				-0.0001	-0.0001	-0.0001	-0.0001	-0.0001
				(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Return On Equity					0.0001	-0.0001	0.00002	0.00006
					(0.0004)	(0.0004)	(0.0004)	(0.0004)
Environmental Pillar						0,011		
						(0.01)		
Governance Pillar							-0,003	
							(0.016)	
Social Pillar								0.02*
								(0.012)
2011	-0.083*	-.135**	-.134**	-.134**	-.133**	-.126**	-.139**	-.133**
	(0.05)	(0.061)	(0.061)	(0.061)	(0.062)	(0.064)	(0.062)	(0.061)
2012	0.058	0.008	0.008	0.008	0.009	0.021	0.004	0.011
	(0.05)	(0.062)	(0.062)	(0.062)	(0.062)	(0.064)	(0.062)	(0.062)
2013	-0.09	-0.065	-0.066	-0.066	-0.066	-0.055	-0.076	-0.067
	(0.066)	(0.083)	(0.083)	(0.083)	(0.084)	(0.09)	(0.084)	(0.083)
2015	-0.047	-0.1	-0.102	-0.106*	-0.105	-0.098	-0.111*	-0.108*
	(0.05)	(0.064)	(0.064)	(0.064)	(0.064)	(0.066)	(0.064)	(0.063)
2016	-0.058	-0.116*	-0.116*	-0.118*	-0.118*	-0.102	-0.123*	-0.12*
	(0.054)	(0.068)	(0.068)	(0.068)	(0.068)	(0.074)	(0.068)	(0.068)
2018	-0.019	-0.079	-0.08	-0.083	-0.083	-0.078	-0.087	-0.088
	(0.049)	(0.063)	(0.064)	(0.064)	(0.064)	(0.066)	(0.064)	(0.064)
2020	-0.02	-0.065	-0.067	-0.069	-0.068	-0.062	-0.069	-0.077
	(0.049)	(0.064)	(0.064)	(0.064)	(0.065)	(0.066)	(0.065)	(0.065)
2021	-0.075	-0.128*	-0.13**	-.133**	-.132**	-.141**	-.132**	-.141**
	(0.049)	(0.065)	(0.066)	(0.066)	(0.066)	(0.068)	(0.066)	(0.066)
Constant	-0.063	-0.437	-0.468	-0.496	-0.497	-0.423	-0.468	-0.479
	(0.089)	(0.314)	(0.319)	(0.32)	(0.32)	(0.432)	(0.322)	(0.318)
Observations	834	707	706	706	706	562	706	706
Overall R-squared	0.126	0.132	0.133	0.135	0.135	0.19	0.134	0.138

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 16- ESG Progressive Regressions with Year-fixed effect, CAPM [-5,10]

4.4.3.2. CO_2 and components

The introduction of year-fixed effects in CO_2 regressions leads to notable changes, particularly in firm size and indirect emissions, while CO_2 Total Emissions remain insignificant, reinforcing that investors do not systematically price emissions into short-term abnormal returns after climate events.

A key difference is the Total Assets coefficient shifting from negative to positive after controlling for year-specific factors. Previously, larger firms were linked to lower CAARs, possibly due to media scrutiny or regulatory concerns.

Another significant finding is the consistent positive coefficient for CO_2 Indirect Emissions, while Scope 3 emissions remain negative. This suggests investors view purchased energy (Indirect Emissions) as an indicator of operational scale, whereas higher supply chain emissions (Scope 3) signal uncertainty and regulatory risk. That these relationships persist after controlling for macroeconomic effects strengthens this interpretation.

Quick Ratio, Total Debt/Common Equity, and ROE remain insignificant, consistent with prior findings and (Fama & French, 1992), which suggest that traditional financial ratios do not reliably predict short-term stock reactions during crises.

The increase in R^2 values across models indicates that accounting for year-specific market dynamics improves explanatory power, highlighting the role of macroeconomic conditions in shaping investor responses to climate events.

CAPM CAAR [-10,10]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CO2 Total Emissions	0,003	0,011	0,01	0,011	0,01			
	(0.014)	(0.016)	(0.016)	(0.016)	(0.016)			
Total Assets		-0.032	-0.031	-0.03	-0.032	0.009	-0.0002	0.069
		(0.04)	(0.04)	(0.04)	(0.04)	(0.059)	(0.057)	(0.06)
Quick Ratio			0.007	0.006	0.005	0.006	0.002	0.048*
			(0.017)	(0.017)	(0.017)	(0.021)	(0.021)	(0.026)
Total Debt / Common Equity				-0.00004	0.00002	-0.0003	-0.001*	0.0001
				(0.0001)	(0.0002)	(0.0003)	(0.0002)	(0.0002)
Return On Equity					0.0004	0.0001	-0.00008	0.0001
					(0.001)	(0.001)	(0.001)	(0.001)
CO2 Direct Emissions						-0,004		
						(0.009)		
CO2 Indirect Emissions							0,03	
							(0.02)	
CO2 Indirect Emissions Scope 3								-0,007
								(0.007)
2011	-0.045	0.023	0.017	0.016	0.024	-0.056	-0.018	-0.159
	(0.1)	(0.119)	(0.12)	(0.12)	(0.121)	(0.138)	(0.135)	(0.135)
2012	0.055	0.121	0.116	0.115	0.121	0.026	0.062	-0.056
	(0.1)	(0.118)	(0.119)	(0.119)	(0.119)	(0.136)	(0.133)	(0.134)
2013	-0.161	0.04	0.031	0.03	0.032	-0.04	0.028	
	(0.114)	(0.141)	(0.143)	(0.143)	(0.144)	(0.156)	(0.153)	
2015	-0.064	0.014	0.007	0.004	0.007	-0.077	-0.04	-0.19
	(0.1)	(0.12)	(0.121)	(0.122)	(0.122)	(0.143)	(0.139)	(0.14)
2016	-0.058	-0.005	-0.016	-0.019	-0.01	-0.092	-0.076	-0.258
	(0.104)	(0.136)	(0.139)	(0.14)	(0.141)	(0.176)	(0.171)	(0.175)
2018	-0.029	0.043	0.036	0.033	0.039	-0.052	-0.015	-0.156
	(0.099)	(0.122)	(0.124)	(.124)	(0.125)	(0.145)	(0.141)	(0.144)
2020	-0.026	0.033	0.026	0.024	0.029	-0.048	-0.015	-0.189
	(0.099)	(0.123)	(0.124)	(0.125)	(0.125)	(0.146)	(0.142)	(0.144)
2021	-0.078	-0.004	-0.011	-0.014	-0.009	-0.105	-0.071	-0.237
	(0.099)	(0.126)	(0.127)	(0.128)	(0.128)	(0.151)	(0.147)	(0.15)
Constant	0.001	0.463	0.447	0.418	0.473	-0.092	-0.309	-1.218
	(0.199)	(0.722)	(0.724)	(0.733)	(0.739)	(1.06)	(1.055)	(1.122)
Observations	440	331	331	331	331	265	274	195
Overall R-squared	0.126	0.118	0.119	0.119	0.12	0.108	0.112	0.207

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 17- CO_2 Progressive Regressions with Year-fixed effect, CAPM [-10,10]

5. Limitations and Constraints

Several limitations should be acknowledged in order to appropriately interpret the results.

First, the analysis focuses on Asian technology firms, which, while relevant given the sector's exposure to climate risks, should not be generalizable to other industries or regions with different market structures and regulatory environments. Second, the event study methodology, though widely used in financial research, assumes that market reactions to climate events are immediate and fully reflect all available information, potentially overlooking longer-term effects or delayed investor responses. Additionally, the choice of asset pricing models (CAPM and 5FF) influences the interpretation of results, as more complex models may dilute ESG's significance by accounting for additional firm-level characteristics. Lastly, external factors could impact stock price reactions in ways that are difficult to isolate, suggesting the need for further research to incorporate broader macroeconomic and policy-driven influences in understanding ESG's role in financial resilience.

5.2 Future Research

Future research could expand on this study's limitations to deepen our understanding of climate events' impact on financial markets.

Industry comparisons: While this study focuses on the Asian technology sector, future research could explore whether ESG factors provide similar protective effects in other industries, such as manufacturing, finance, or energy.

External factors: This study emphasizes firm-level characteristics, but macroeconomic conditions and policy interventions—which showed some significance in year-fixed effects regressions—also influence stock price reactions. Future research could examine the role of government relief programs and carbon regulations in shaping market responses to extreme weather events.

Beyond short-term reactions: The event study methodology assumes immediate market responses, but future studies could explore long-term effects, such as recovery patterns, shifts in investor sentiment, and changes in corporate strategies.

6. Conclusion

Our results suggest that firms with higher ESG scores experience weaker negative stock price reactions to climate events, though this effect is more consistently observed in CAPM. The 5FF model, which controls for size, value, profitability, and investment, shows lower statistical significance, implying that ESG’s role in moderating financial shocks is likely linked to broad market movements and investor sentiment rather than firm-specific return drivers. This aligns with (Pedersen et al, 2021), who argues that ESG integration affects portfolio risk-adjusted returns primarily through investor perception.

Year-fixed effects analysis indicates that ESG’s influence fluctuates over time, suggesting that market conditions and investor preferences shape how ESG factors are priced—supporting (Dyck et al., 2019), who emphasizes institutional investors' role in ESG engagement.

A key finding is that firms with higher CO_2 emissions face stronger negative abnormal returns after climate disasters. This aligns with (Bolton & Kacperczyk, 2021), reinforcing that carbon-related risks are increasingly priced into stock returns, highlighting the growing financial materiality of environmental performance.

Overall, this study provides evidence that ESG can buffer climate-related financial shocks, though its impact depends on market conditions and the asset pricing model used. The stronger CAPM results suggest investor sentiment plays a key role in market resilience, but this effect weakens when firm-level financial factors are controlled for. These findings contribute to discussions on sustainable investing and financial risk mitigation, offering insights for investors, policymakers, and corporate leaders. Future research should further explore the interplay between ESG, firm fundamentals, and regulatory policies to refine methodologies isolating ESG’s role in financial resilience.

Declaration:

I acknowledge the use of Artificial Intelligence to improve the text quality and reduce word count. The AI tool was employed for language refinement, including improving clarity. All content was reviewed and edited to ensure accuracy and obedience to academic standards.

7. Appendix

7.1 Climate Events

Country	Disaster Subgroup	Disaster Type	Start Year	Start Month	Start Day	Total Deaths	Total Affected	Total Damage ('000 US$)
Japan	Meteorological	Storm	2015	7	16	2	845	207000
	Meteorological	Storm	2011	9	2	68	1300	650000
	Hydrological	Flood	2012	7	12	30	48135	1400000
	Hydrological	Flood	2015	9	9	21	45046	1400000
	Meteorological	Storm	2011	9	22	13	308	1820000
	Meteorological	Storm	2021	1	7	23	394	2000000
	Meteorological	Storm	2018	9	28	4	18200	4500000
	Hydrological	Flood	2020	6	29	82	250114	5800000
	Hydrological	Flood	2018	6	29	246	1500102	9500000
	Meteorological	Storm	2018	9	4	17	3900	12500000
South Korea	Meteorological	Storm	2021	8	23		600	13000
	Hydrological	Flood	2011	7	27	53	29000	52000
	Meteorological	Storm	2016	10	5	9	1500	126000
	Meteorological	Storm	2016	1	20	6	-	127000
	Meteorological	Storm	2012	9	15		3120	349000
	Hydrological	Flood	2020	8	1	42	6000	420000
	Meteorological	Storm	2012	8	28	20	-	450000
	Meteorological	Storm	2020	9	6	2	-	1200000
	Hydrological	Flood	2020	7	13	10	9000	-
	Meteorological	Storm	2010	9	2	12	41500	-
China	Hydrological	Flood	2020	8	1	92		4800000
	Hydrological	Flood	2013	8	12	118	1075000	4960000
	Meteorological	Storm	2018	8	15	53	39600	5400000
	Hydrological	Flood	2011	6	1	467	67900000	6400000
	Meteorological	Storm	2013	10	7	8	475000	6700000
	Hydrological	Flood	2012	7	21	151	1000000	8000000
	Hydrological	Flood	2021	6	1	352	14500000	16500000
	Hydrological	Flood	2020	5	21	280	4200000	17000000
	Hydrological	Flood	2010	5	29	1691	134000000	18000000
	Hydrological	Flood	2016	6	28	289	60000000	22000000

Table 18- Events' Data

7.2 Year-Fixed Regressions

7.2.1 ESG Score and Components

5FF CAAR [-5,10]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESG Score	0.025	0.027	0.027	0.025	0.025			
	(0.021)	(0.023)	(0.023)	(0.024)	(0.024)			
Total Assets		0.004	0.004	0.005	0.005	0.013	0.008	0.007
		(0.019)	(0.019)	(0.019)	(0.019)	(0.027)	(0.019)	(0.019)
Quick Ratio			0.001	0.001	0.001	-0.004	0.001	0.001
			(0.006)	(0.006)	(0.006)	(0.007)	(0.006)	(0.006)
Total Debt / Common Equity				-0.0001	-0.0001	-0.0001	-0.0001	-0.0001
				(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Return On Equity					0.0001	-0.0001	0.00002	0.00006
					(0.0004)	(0.0004)	(0.0004)	(0.0004)
Environmental Pillar						0.011		
						(0.011)		
Governance Pillar							0.014	
							(0.016)	
Social Pillar								0.014
								(0.012)
2011	-0.047	-0.072	-0.072	-0.072	-0.072	-0.086	-0.075	-0.076
	(0.049)	(0.062)	(0.062)	(0.062)	(0.063)	(0.068)	(0.062)	(0.062)
2012	0.068	0.042	0.042	0.042	0.042	0.035	0.039	0.039
	(0.049)	(0.062)	(0.062)	(0.062)	(0.063)	(0.068)	(0.063)	(0.063)
2013	-0.007	-0.004	-0.004	-.004	-0.005	-0.015	-0.007	-0.012
	(0.065)	(0.084)	(0.084)	(0.084)	(0.084)	(0.096)	(0.084)	(0.084)
2015	-0.004	-0.026	-0.027	-0.029	-0.029	-0.039	-0.03	-0.035
	(0.049)	(0.064)	(0.064)	(0.064)	(0.065)	(0.07)	(0.065)	(0.064)
2016	-0.031	-0.062	-0.062	-0.064	-0.064	-0.071	-0.066	-0.07
	(0.053)	(0.069)	(0.069)	(0.069)	(0.069)	(0.079)	(0.069)	(0.069)
2018	0.012	-0.018	-0.019	-.021	-0.021	-0.034	-0.02	-0.027
	(0.049)	(0.064)	(0.064)	(.064)	(0.065)	(0.071)	(0.065)	(0.064)
2020	-0.015	-0.043	-.043	-.045	-.045	-0.054	-0.042	-0.051
	(0.048)	(0.065)	(0.065)	(.065)	(0.065)	(0.071)	(0.065)	(0.065)
2021	-0.062	-0.089	-0.089	-.091	-0.091	-0.124*	-0.087	-0.096
	(0.049)	(0.066)	(0.066)	(0.066)	(0.067)	(0.073)	(0.067)	(0.067)
Constant	-0.082	-0.125	-.134	-0.152	-0.152	-0.209	-.157	-0.123
	(0.088)	(0.317)	(0.322)	(0.323)	(0.323)	(0.46)	(0.325)	(0.322)
Observations	834	707	706	706	706	562	706	706
Overall R-squared	0.103	0.094	0.094	0.095	0.095	0.151	0.094	0.095

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 19- ESG Progressive Regressions with Year-fixed effect, 5FF [-5,10]

CAPM CAAR [-10,10]	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESG Score	0,011	0,014	0,016	0,013	0,014			
	(0.023)	(0.025)	(0.025)	(0.025)	(0.025)			
Total Assets		0.026	0.027	0.029	0.029	0.003	0.031	0.027
		(0.02)	(0.021)	(0.021)	(0.021)	(0.027)	(0.02)	(0.02)
Quick Ratio			0.004	0.003	0.003	-0.001	0.003	0.004
			(0.006)	(0.006)	(0.006)	(0.007)	(0.006)	(0.006)
Total Debt / Common Equity				-0.0001	-0.0001	6.54e- 06	-0.0001	-.00008
				(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Return On Equity					0.0002	0.0004	0.0002	0.0002
					(0.0004)	(0.0004)	(0.0004)	(0.0004)
Environmental Pillar						0.007		
						(0.011)		
Governance Pillar							-0.005	
							(0.017)	
Social Pillar								0.021*
								(0.013)
2011	-0.154***	-0.12*	-0.119*	-0.119*	-0.115*	-0.07	-0.12*	-0.114*
	(0.053)	(0.067)	(0.067)	(0.067)	(0.067)	(0.068)	(0.067)	(0.067)
2012	-0.061	-0.029	-0.029	-0.029	-0.025	0.019	-0.031	-0.022
	(0.054)	(0.067)	(0.067)	(0.067)	(0.067)	(0.069)	(0.067)	(0.067)
2013	-0.287***	-0.141	-.142	-0.142	-0.14	-0.089	-0.15*	-0.139
	(0.07)	(0.091)	(0.091)	(0.091)	(0.091)	(0.097)	(0.091)	(0.09)
2015	-0.154***	-0.123*	-0.124*	-0.128*	-0.126*	-0.084	-.132*	-0.127*
	(0.054)	(0.069)	(0.069)	(0.069)	(0.069)	(0.071)	(0.07)	(0.069)
2016	-0.173***	-.156**	- 0.156**	- 0.159**	- 0.155**	-0.094	-.161**	-.157**
	(0.058)	(0.074)	(0.074)	(0.074)	(0.074)	(0.08)	(0.074)	(0.074)
2018	-0.119**	-.095	-0.097	-0.1	-0.097	-0.05	-.101	-0.102
	(0.053)	(0.069)	(0.069)	(0.069)	(0.069)	(0.071)	(0.07)	(0.069)
2020	-0.096*	-.074	-0.076	-0.078	-.075	-0.029	-.076	-0.084
	(0.052)	(.07)	(0.07)	(0.07)	(0.07)	(0.072)	(0.07)	(0.07)
2021	-0.176***	- 0.156**	- 0.158**	-0.16**	- 0.157**	-.123*	- 0.158**	- 0.167**
	(0.053)	(0.071)	(0.071)	(0.071)	(0.072)	(0.073)	(0.072)	(0.072)
Constant	0.083	-0.428	-0.46	-0.485	-0.49	-0.019	-0.458	-0.476
	(0.095)	(0.341)	(0.346)	(0.347)	(0.348)	(0.465)	(0.349)	(0.345)
Observations	834	707	706	706	706	562	706	706
Overall R-squared	0.132	0.114	0.115	0.116	0.117	0.165	0.116	0.121

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 20- ESG Progressive Regressions with Year-Fixed Effects CAPM [-10,10]

5FF CAAR [-10,10]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESG Score	0.014	0.018	0.018	0.016	0.018			
	(0.022)	(0.024)	(0.024)	(0.024)	(0.025)			
Total Assets		0.001	0.001	0.002	0.002	-0.011	0.004	0.001
		(0.02)	(0.02)	(0.02)	(0.02)	(0.026)	(0.02)	(0.02)
Quick Ratio			-0.001	-0.001	-0.001	-0.008	-0.002	0
			(0.006)	(0.006)	(0.006)	(0.007)	(0.006)	(0.006)
Total Debt / Common Equity				-0.0001	-0.0001	6.54e-06	-0.0001	- 0.00008
				(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Return On Equity					0.0002	0.0004	0.0002	0.0002
					(0.0004)	(0.0004)	(0.0004)	(0.0004)
Environmental Pillar						0.002		
						(0.011)		
Governance Pillar							0.003	
							(0.017)	
Social Pillar								0.019
								(0.012)
2011	-.118**	-0.054	-0.054	-0.055	-0.049	-0.031	-0.053	-0.05
	(0.051)	(0.064)	(0.064)	(0.064)	(0.065)	(0.066)	(0.065)	(0.064)
2012	-0.056	0.001	0.001	0.002	0.006	0.027	0.002	0.007
	(0.051)	(0.064)	(0.065)	(0.065)	(0.065)	(0.067)	(0.065)	(0.065)
2013	- .223***	-0.095	-0.095	-0.096	-0.092	-0.074	-0.098	-0.094
	(0.067)	(0.087)	(0.087)	(0.087)	(0.087)	(0.094)	(0.087)	(0.086)
2015	-0.095*	-0.032	-0.032	-0.033	-0.031	-0.01	-0.034	-0.034
	(0.051)	(0.066)	(0.066)	(0.067)	(0.067)	(0.069)	(0.067)	(0.066)
2016	- .154***	-0.095	-0.095	-0.096	-0.091	-0.06	-0.095	-0.094
	(0.055)	(0.071)	(0.071)	(0.071)	(0.071)	(0.077)	(0.071)	(0.071)
2018	-0.084*	-0.024	-0.024	-0.025	-0.022	0.001	-0.024	-0.027
	(0.05)	(0.066)	(0.066)	(0.066)	(0.067)	(0.069)	(0.067)	(0.066)
2020	- 0.107**	-0.045	-0.045	-0.045	-0.041	-0.016	-0.041	-0.049
	(0.05)	(0.067)	(0.067)	(0.067)	(0.067)	(0.069)	(0.068)	(0.068)
2021	- .167***	-0.104	-0.103	-0.104	-0.1	-0.093	-0.099	-0.108
	(0.05)	(0.068)	(0.068)	(0.069)	(0.069)	(0.071)	(0.069)	(0.069)
Constant	0.057	-0.036	-0.03	-0.042	-0.049	0.233	-0.035	-0.03
	(0.091)	(0.328)	(0.333)	(0.334)	(0.334)	(0.451)	(0.336)	(0.332)
Observations	834	707	706	706	706	562	706	706
Overall R-squared	0.101	0.079	0.079	0.08	0.081	0.147	0.08	0.084

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 21 – ESG Progressive Regressions with Year-Fixed Effects 5FF [-10,10]

CAPM CAAR [-5,5]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESG Score	0.015	0.015	0.016	0.013	0.015			
	(0.018)	(0.02)	(0.02)	(0.02)	(0.02)			
Total Assets		0.013	0.013	0.016	0.015	0.024	0.018	0.015
		(0.016)	(0.016)	(0.017)	(0.017)	(0.022)	(0.016)	(0.016)
Quick Ratio			0.001	0.001	0.001	0.001	0.001	0.001
			(0.005)	(0.005)	(0.005)	(0.006)	(0.005)	(0.005)
Total Debt / Common Equity				-0.0001	-0.0001	-0.0001	-0.0001	-0.0001
				(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Return On Equity					0.0003	0.00003	0.0002	0.0003
					(0.0003)	(0.0003)	(0.0003)	(0.0003)
Environmental Pillar						0.004		
						(0.009)		
Governance Pillar							-0.005	
							(0.014)	
Social Pillar								0.015
								(0.01)
2011	0.017	-0.084	-0.084	-0.083	-0.079	-0.078	-0.085	-0.08
	(0.042)	(0.053)	(0.053)	(0.053)	(0.054)	(0.055)	(0.053)	(0.053)
2012	0.102**	0.007	0.007	0.007	0.011	0.015	0.006	0.012
	(0.042)	(0.054)	(0.054)	(0.054)	(0.054)	(0.055)	(0.054)	(0.054)
2013	-0.018	-0.057	-.057	-0.057	-0.055	-0.077	-0.065	-0.057
	(0.055)	(0.072)	(0.072)	(0.072)	(0.072)	(0.078)	(0.072)	(0.072)
2015	0.015	-0.08	-.08	-0.084	-0.081	-0.083	-0.087	-0.084
	(0.042)	(0.055)	(.055)	(0.055)	(0.055)	(0.057)	(0.055)	(0.055)
2016	0.031	-0.07	-.07	-0.073	-0.068	-0.072	-0.074	-0.071
	(0.045)	(0.059)	(0.059)	(0.059)	(0.059)	(0.064)	(0.059)	(0.059)
2018	0.049	-0.054	-0.054	-0.057	-.054	-0.058	-0.058	-0.058
	(0.041)	(0.055)	(0.055)	(0.055)	(0.055)	(0.057)	(0.055)	(0.055)
2020	0.063	-0.043	-0.044	-.046	-0.042	-0.041	-0.043	-.048
	(0.041)	(0.056)	(0.056)	(0.056)	(0.056)	(0.057)	(0.056)	(0.056)
2021	0.002	-0.105*	-0.106*	-0.108*	-0.104*	-.116**	-0.105*	-.111*
	(0.041)	(0.057)	(0.057)	(0.057)	(0.057)	(0.059)	(0.057)	(0.057)
Constant	-0.099	-0.237	-0.249	-.273	-0.28	-.403	-0.248	-0.264
	(0.074)	(0.272)	(0.276)	(0.277)	(0.277)	(0.373)	(0.279)	(0.276)
Observations	834	707	706	706	706	562	706	706
Overall R-squared	0.125	0.115	0.115	0.117	0.118	0.173	0.118	0.121

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 22- ESG Progressive Regressions with Year-Fixed Effects CAPM [-5,5]

5FF CAAR [-5,5]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESG Score	0.017	0.02	0.019	0.017	0.02			
	(0.016)	(0.018)	(0.018)	(0.019)	(0.019)			
Total Assets		-0.002	-0.003	-0.001	-0.002	0.016	0.001	-0.001
		(0.015)	(0.015)	(0.015)	(0.015)	(0.02)	(0.015)	(0.015)
Quick Ratio			-0.001	-0.001	-0.001	-0.002	-0.002	-0.001
			(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Total Debt / Common Equity				-0.0001	-0.0001	-0.0002	-0.0003	-.00003
				(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0001)
Return On Equity					0.0002	-4.38e-08	-0.0002	0.00008
					(0.0004)	(0.001)	(0.001)	(0.001)
Environmental Pillar						0.005		
						(0.008)		
Governance Pillar							0.004	
							(0.013)	
Social Pillar								0.011
								(0.009)
2011	0.038	-0.043	-0.043	-0.043	-0.035	-0.052	-0.04	-0.038
	(0.038)	(0.049)	(0.049)	(0.049)	(0.049)	(0.051)	(0.049)	(0.049)
2012	0.118***	0.041	0.041	0.041	0.049	0.037	0.044	0.047
	(0.039)	(0.049)	(0.049)	(0.049)	(0.049)	(0.051)	(0.049)	(0.049)
2013	0.029	-0.011	-0.011	-0.011	-0.006	-0.051	-0.013	-0.014
	(0.051)	(0.066)	(0.066)	(0.066)	(0.066)	(0.071)	(0.066)	(0.066)
2015	0.055	-0.018	-0.017	-0.02	-0.015	-0.032	-0.019	-0.02
	(0.039)	(0.051)	(0.051)	(0.051)	(0.051)	(0.052)	(0.051)	(0.05)
2016	0.046	-0.024	-0.024	-0.026	-0.018	-0.039	-0.022	-0.023
	(0.042)	(0.054)	(0.054)	(0.054)	(0.054)	(0.059)	(0.054)	(0.054)
2018	0.076**	-0.002	-0.001	-0.004	0.002	-0.018	0	-0.002
	(0.038)	(0.05)	(0.05)	(0.051)	(0.051)	(0.053)	(0.051)	(0.051)
2020	0.06	-0.016	-0.015	-0.016	-0.01	-0.023	-0.009	-0.015
	(0.038)	(0.051)	(0.051)	(0.051)	(0.051)	(0.053)	(0.051)	(0.051)
2021	0.013	-0.063	-0.062	-0.064	-0.058	-0.091*	-0.056	-0.062
	(0.038)	(0.052)	(0.052)	(0.052)	(0.052)	(0.054)	(0.052)	(0.052)
Constant	-0.127*	-0.014	-0.009	-0.026	-0.037	-0.289	-0.022	-0.014
	(0.069)	(0.25)	(0.253)	(0.254)	(0.254)	(0.343)	(0.255)	(0.253)
Observations	834	707	706	706	706	562	706	706
Overall R-squared	0.113	0.107	0.107	0.108	0.113	0.182	0.111	0.113

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 23- ESG Progressive Regressions with Year-Fixed Effects 5FF [-5,5]

7.1.2 CO_2 and Components

CAPM CAAR [-5,10]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CO2 Total Emissions	0.007	0.007	0.007	0.008	0.008			
	(0.014)	(0.015)	(0.015)	(0.015)	(0.015)			
Total Assets		0.001	0.002	0.004	0.004	0.042	0.032	0.092
		(0.037)	(0.037)	(0.038)	(0.038)	(0.055)	(0.052)	(0.057)
Quick Ratio			0.001	0.001	0.001	0.008	0.005	0.04
			(0.016)	(0.016)	(0.016)	(0.019)	(0.02)	(0.024)
Total Debt / Common Equity				-0.00007	-0.00006	-0.0003	-0.001*	-0.0002
				(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Return On Equity					0.00002	-0.001	-0.001	-0.001
					(0.001)	(0.001)	(0.001)	(0.001)
CO2 Direct Emissions						-0,002		
						-0,008		
CO2 Indirect Emissions							0,023	
							-0,019	
CO2 Indirect Emissions Scope 3								-0,009
								-0,006
2011	-0,087	-0,093	-0,095	-0,097	-0,096	-0,167	-0,134	-0.249*
	(0.098)	(0.111)	(0.112)	(0.112)	(0.113)	(0.127)	(0.125)	(0.127)
2012	0,07	0,069	0,068	0,066	0,066	-0,024	0,008	-0,088
	(0.098)	(0.11)	(0.111)	(0.111)	(0.112)	(0.125)	(0.123)	(0.126)
2013	-0,104	-0,003	-0,005	-0,007	-0,007	-0,071	-0,018	
	(0.111)	(0.132)	(0.134)	(0.134)	(0.134)	(0.143)	(0.141)	
2015	-0,062	-0,062	-0,064	-0,069	-0,069	-0,152	-0,119	-0.245*
	(0.098)	(0.112)	(0.114)	(0.114)	(0.114)	(0.131)	(0.128)	(0.133)
2016	-0,069	-0,087	-0,09	-0,094	-0,094	-0,171	-0,154	-0.304*
	(0.102)	(0.127)	(0.13)	(0.131)	(0.132)	(0.161)	(0.159)	(0.165)
2018	-0,03	-0,039	-0,041	-0,046	-0,046	-0,138	-0,103	-0.22
	(0.097)	(0.114)	(0.116)	(0.116)	(0.117)	(0.133)	(0.131)	(0.136)
2020	-0,058	-0,049	-0,05	-0,055	-0,055	-0,132	-0,104	-0.245*
	(0.097)	(0.115)	(0.116)	(0.116)	(0.117)	(0.134)	(0.132)	(0.136)
2021	-0,093	-0,096	-0,097	-0,103	-0,102	-0,205	-0,174	-.318**
	(0.097)	(0.117)	(0.119)	(0.12)	(0.12)	(0.138)	(0.136)	(0.141)
Constant	-0,025	-0,051	-0,055	-0,109	-0,107	-0,66	-0,775	-1,551
	-0,195	(0.675)	(0.677)	(0.686)	(0.691)	(0.972)	(0.976)	(1.059)
Observations	440	331	331	331	331	265	274	195
Overall R-squared	0,173	0,203	0,203	0,204	0,204	0,188	0,187	0,307

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 24- CO_2 Progressive Regressions with Year-Fixed Effects CAPM [-5,10]

5FF CAAR [-5,10]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CO2 Total Emissions	0.004	0.011	0.012	0.013	0.013			
	(0.013)	(0.015)	(0.015)	(0.015)	(0.015)			
Total Assets		-0.002	-0.004	-0.002	-0.001	0.028	0.023	0.07
		(0.038)	(0.038)	(0.038)	(0.038)	(0.057)	(0.055)	(0.06)
Quick Ratio			-0.007	-0.007	-0.006	-0.007	-0.011	0.022
			(0.016)	(0.016)	(0.016)	(0.02)	(0.02)	(0.025)
Total Debt / Common Equity				-0.00006	-0.00008	-0.0004	-0.001*	-0.0002
				(0.0001)	(0.0002)	(0.0002)	(0.0003)	(0.0002)
Return On Equity					-0.0002	-0.001	-0.001	-0.001
					(0.001)	(0.001)	(0.001)	(0.001)
CO2 Direct Emissions						0.002		
						(0.008)		
CO2 Indirect Emissions							0.024	
							(0.02)	
CO2 Indirect Emissions Scope 3								-0.008
								(0.007)
2011	-0.043	-0.028	-0.022	-0.023	-0.027	-0.067	-0.043	-0.148
	(0.095)	(0.113)	(0.114)	(0.114)	(0.115)	(0.132)	(0.13)	(0.134)
2012	0.099	0.119	0.124	0.122	0.12	.0055	0.076	-0.008
	(0.095)	(0.112)	(0.113)	(0.113)	(.0113)	(0.13)	(0.128)	(0.133)
2013	0.004	0.048	0.057	0.055	0.055	0.007	0.046	
	(0.108)	(0.134)	(0.136)	(0.136)	(0.137)	(0.149)	(0.147)	
2015	-0.005	0.02	0.027	0.022	0.021	-0.044	-0.021	-0.12
	(0.095)	(0.114)	(0.115)	(0.116)	(0.116)	(0.136)	(0.133)	(0.14)
2016	-0.035	-0.047	-0.036	-0.039	-0.043	-0.098	-0.094	-0.214
	(0.099)	(0.129)	(0.132)	(0.133)	(0.134)	(0.168)	(0.165)	(0.174)
2018	0.017	0.031	0.038	0.034	0.031	-0.04	-0.017	-0.105
	(0.095)	(0.116)	(0.117)	(0.118)	(0.119)	(0.139)	(0.136)	(0.143)
2020	-0.03	-0.024	-0.017	-0.021	-0.023	-0.083	-0.066	-0.174
	(0.094)	(0.117)	(0.118)	(0.118)	(0.119)	(0.14)	(0.137)	(0.143)
2021	-0.066	-0.052	-0.045	-0.049	-0.051	-0.133	-0.112	-0.237
	(0.095)	(0.119)	(0.121)	(0.122)	(0.122)	(0.144)	(0.142)	(0.149)
Constant	-0.033	-0.079	-0.063	-0.107	-0.131	-0.456	-0.643	-1.176
	(0.19)	(0.686)	(0.688)	(0.697)	(0.703)	(1.012)	(1.015)	(1.115)
Observations	440	331	331	331	331	265	274	195
Overall R-squared	0.185	0.204	0.205	0.205	0.206	0.196	0.204	0.32

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 25- CO_2 Progressive Regressions with Year-Fixed Effects 5FF [-5,10]

5FF CAAR [-10,10]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CO2 Total Emissions	.003	.01	0.01	0.01	0.009			
	(.013)	(.015)	(0.015)	(0.016)	(0.016)			
Total Assets		-.033	-0.034	-0.035	-0.036	0.007	0.0003	0.043
		(.039)	(0.039)	(0.039)	(0.04)	(0.061)	(0.058)	(0.065)
Quick Ratio			-0.004	-0.004	-0.005	-0.015	-0.02	0.019
			(0.017)	(0.017)	(0.017)	(0.022)	(0.022)	(0.027)
Total Debt / Common Equity				0.00002	0.00005	-0.0003	-0.0004	0.0001
				(0.0001)	(0.0001)	(0.0003)	(0.0003)	(0.0002)
Return On Equity					0.0002	-0.0003	-0.001	0.0002
					(0.001)	(0.001)	(0.001)	(0.001)
CO2 Direct Emissions						-0.002		
						(0.009)		
CO2 Indirect Emissions							0.031	
							(0.021)	
CO2 Indirect Emissions Scope 3								-0.002
								(0.007)
2011	0.006	0.072	0.075	0.076	0.08	0.026	0.059	-0.054
	(0.096)	(0.116)	(0.117)	(0.118)	(0.118)	(0.141)	(0.138)	(0.144)
2012	0.087	0.145	0.148	0.149	0.152	0.072	0.103	0.02
	(0.096)	(0.115)	(0.116)	(0.116)	(0.117)	(0.139)	(0.135)	(0.143)
2013	-0.064	0.076	0.081	0.082	0.083	0.016	0.077	
	(0.109)	(0.138)	(0.14)	(0.14)	(0.141)	(0.159)	(0.156)	
2015	0.026	0.095	0.099	0.101	0.103	0.02	0.051	-0.041
	(0.096)	(0.117)	(0.119)	(0.119)	(0.12)	(0.146)	(0.141)	(0.15)
2016	-0.032	0.027	0.035	0.036	0.041	-0.043	-0.034	-0.155
	(0.1)	(0.133)	(0.136)	(0.137)	(0.138)	(0.18)	(0.175)	(0.187)
2018	0.039	0.105	0.109	0.111	0.114	0.026	.0057	-0.03
	(0.095)	(0.119)	(0.121)	(0.121)	(0.122)	(0.148)	(.0144)	(0.154)
2020	0.001	0.064	0.069	0.07	0.073	-0.003	0.025	-0.095
	(0.095)	(0.12)	(0.121)	(0.122)	(0.122)	(0.149)	(0.145)	(0.154)
2021	-0.051	0.021	0.026	0.028	0.03	-0.064	-0.035	-0.157
	(0.095)	(0.123)	(0.124)	(0.125)	(0.126)	(0.154)	(0.15)	(0.16)
Constant	-0.044	0.457	0.467	0.487	0.515	-0.078	-0.347	-0.816
	(0.191)	(0.706)	(0.708)	(0.717)	(0.723)	(1.083)	(1.075)	(1.2)
Observations	440	331	331	331	331	265	274	195
Overall R-squared	0.141	0.135	0.136	0.136	0.136	0.144	0.156	0.225

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 26- CO_2 Progressive Regressions with Year-fixed effect, 5FF [-10,10]

CAPM CAAR [-5,5]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CO2 Total Emissions	0,011	0,01	0,01	0,013	0,013			
	(0.01)	(0.011)	(0.011)	(0.011)	(0.012)			
Total Assets	0.006	0.006	0.011	0.011	0.043	0.033	0.079*	
	(0.029)	(0.029)	(0.029)	(0.029)	(0.043)	(0.042)	(0.043)	
Quick Ratio		0.002	0.001	0.001	0.02	0.017	0.023	
		(0.012)	(0.012)	(0.012)	(0.015)	(0.016)	(0.018)	
Total Debt / Common Equity			-0.0001	-0.00002	0.001	-0.0001*	-0.0001	
			(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0 .0001)	
Return On Equity				0.001	0.001	0.001	0.0003	
				(0)	(0.001)	(0.001)	(0.001)	
CO2 Direct Emissions					-0.002			
					(0.006)			
CO2 Indirect Emissions						0.019		
						(0.015)		
CO2 Indirect Emissions Scope 3							-0.004	
							(0.005)	
2011	-0.057	-0.066	-0.068	-0.072	-0.071	-0.145	-0.114	-0.198**
	(0.07)	(0.086)	(0.086)	(0.086)	(0.087)	(0.101)	(0.1)	(0.096)
2012	0.03	0.032	0.03	0.026	0.027	-.064	-0.034	-0.103
	(0.07)	(0.085)	(0.085)	(0.085)	(0.086)	(0.099)	(0.098)	(0.095)
2013	-0.128	-0.055	-0.058	-0.062	-0.062	-0.14	-0.093	
	(0.079)	(0.102)	(0.103)	(0.103)	(0.103)	(0.114)	(0.113)	
2015	-0.075	-0.069	-0.071	-0.082	-.082	-0.168	-0.137	-0.214**
	(0.07)	(0.086)	(0.087)	(0.088)	(0.088)	(0.104)	(0.103)	(0.1)
2016	-0.069	-0.085	-0.089	-0.098	-0.097	-0.157	-0.138	-0.237*
	(0.073)	(0.098)	(0.1)	(0.1)	(0.101)	(0.129)	(0.127)	(0.124)
2018	-0.042	-0.048	-0.05	-0.061	-0.06	-0.152	-0.12	-0.2*
	(0.069)	(0.088)	(0.089)	(0.089)	(0.09)	(0.106)	(0.105)	(0.102)
2020	-0.04	-0.056	-0.058	-0.067	-0.066	-0.146	-0.119	-0.222**
	(0.069)	(0.088)	(0.089)	(0.089)	(0.09)	(0.107)	(0.105)	(0.102)
2021	-0.086	-0.095	-0.098	-0.109	-.108	-0.207*	-0.178	-0.261**
	(0.069)	(0.091)	(0.092)	(0.092)	(0.092)	(0.11)	(0.109)	(0.106)
Constant	-0.077	-0.189	-0.194	-0.305	-0.297	-0.702	-0.76	-1.389*
	(0.139)	(0.52)	(0.522)	(0.526)	(0.531)	(0.775)	(0.782)	(0.796)
Observations	440	331	331	331	331	265	274	195
Overall R-squared	0.182	0.174	0.174	0.181	0.181	0.175	0.171	0.241

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 27- CO_2 Progressive Regressions with Year-Fixed Effects CAPM [-5,5]

5FF CAAR [-5,5]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CO2 Total Emissions	0,01	0,008	0,009	0,011	0,011			
	(0.009)	(0.011)	(0.011)	(0.011)	(0.011)			
Total Assets		0.02	0.02	0.024	0.023	0.054	0.044	0.083*
		(0.027)	(0.027)	(0.028)	(0.028)	(0.043)	(0.041)	(0.045)
Quick Ratio			-0.004	-0.004	-0.005	0.009	0.007	0.004
			(0.012)	(0.012)	(0.012)	(0.015)	(0.015)	(0.019)
Total Debt / Common Equity				-0.0001	-0.0001	-0.0002	-0.0003	-0.00003
				(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0001)
Return On Equity					0.0002	-4.38e-08	-0.0002	0.00008
					(0.0004)	(0.001)	(0.001)	(0.001)
CO2 Direct Emissions						-0,001		
						-0,006		
CO2 Indirect Emissions							0,017	
							-0,015	
CO2 Indirect Emissions Scope 3								0,001
								-0,005
2011	-0,038	-0.077	-0.073	-0.076	-0.073	-0.135	-0.108	-0.18*
	(0.067)	(0.082)	(0.082)	(0.082)	(0.083)	(0.1)	(0.099)	(0.101)
2012	0.05	0.023	0.026	0.023	0.025	-0.058	-0.032	-0.089
	(0.067)	(0.081)	(0.081)	(0.081)	(0.082)	(0.098)	(0.097)	(0.1)
2013	-0.069	-0.057	-0.052	-0.055	-0.054	-0.135	-0.094	
	(0.076)	(0.097)	(0.098)	(0.098)	(0.098)	(0.112)	(0.112)	
2015	-0.03	-0.055	-0.051	-0.06	-0.059	-0.143	-0.115	-0.173
	(0.067)	(0.082)	(0.083)	(0.084)	(0.084)	(0.103)	(0.101)	(0.105)
2016	-0,059	-0,104	-0,097	-0,104	-0,101	-0,151	-0,134	-0,21
	(0.07)	(0.093)	(0.096)	(0.096)	(0.096)	(0.127)	(0.125)	(0.131)
2018	-0.009	-0.046	-0.042	-0.05	-0.048	-0.137	-0.108	-0.173
	(0.066)	(0.084)	(0.085)	(0.085)	(0.085)	(0.105)	(0.103)	(0.108)
2020	-0.029	-0.067	-0.063	-0.07	-0.068	-0.143	-0.12	-0.197*
	(0.066)	(0.084)	(0.085)	(0.085)	(0.086)	(0.106)	(0.104)	(0.108)
2021	-0.075	-0.115	-0.111	-0.12	-0.117	-0.213*	-0.187*	-0.261**
	(0.066)	(0.086)	(0.087)	(0.088)	(0.088)	(0.109)	(0.108)	(0.112)
Constant	-0,093	-0,44	-0,431	-0,519	-0,496	-0.911	-0.953	-1.518*
	(0.133)	(0.496)	(0.497)	(0.502)	(0.506)	(0.766)	(0.772)	(0.84)
Observations	440	331	331	331	331	265	274	195
Overall R-squared	0,196	0,209	0,209	0,214	0,214	0,206	0,204	0,262

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 28- CO_2 Progressive Regressions with Year-Fixed Effects 5FF [-5,5]

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