Investing in a Warming World: A Deep Dive into Investor Awareness and Stock Returns Across European Cities

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Abstract

This paper examines the effect of people's attention to climate change issues on the returns of European stocks from 2005 to 2021. To this end, I use the google Trends' monthly Search Volume Index to proxy the attention to global warming and find no difference in investors' awareness of the risks associated with climate change especially when experiencing extreme weather or after natural disaster shocks in a particular city. However, when examining temperature quartiles at the country level, investors seem less concerned about global warming during both unusually warm and cool months. Contrary to expectations, my results show that stock returns are unrelated to investors' experience with abnormal local weather and natural disaster shocks in both high- and low-carbon emission firms. Surprisingly, when examining temperature quartiles, abnormal temperatures positively impact stock returns.

Moreover, I find a proactive commitment from companies to address climate change during abnormal temperature months, as evidenced by a reduction in carbon emissions. The study contributes to the understanding of investor behavior in the context of climate change, shedding light on the complex dynamics between climate events, public awareness, and financial markets.

Keywords: Climate Change, Investor Awareness, Abnormal Temperatures, Natural Disasters, Carbon Emissions

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Resumo

Este artigo analisa o efeito da atenção das pessoas às questões das alterações climáticas nos retornos das ações europeias de 2005 a 2021. Para o efeito, utilizo o Índice de Volume de Pesquisa mensal do Google Trends como indicador da atenção dada ao aquecimento global e, não encontro qualquer diferença na sensibilização dos investidores para os riscos associados às alterações climáticas, especialmente quando experimentam condições meteorológicas extremas ou após choques de catástrofes naturais numa determinada cidade. No entanto, quando se examinam os quartis de temperatura a nível nacional, os investidores parecem menos preocupados com o aquecimento global durante os meses invulgarmente quentes e frios. Contrariamente às expectativas, os meus resultados mostram que as rendibilidades das ações não estão relacionadas com a experiência dos investidores com condições meteorológicas locais anormais e choques de catástrofes naturais, tanto nas empresas com emissões de carbono elevadas como nas empresas com emissões reduzidas. Surpreendentemente, quando se examinam os quartis de temperatura, as temperaturas anormais têm um impacto positivo na rendibilidade das ações.

Além disso, constato um compromisso pró-ativo das empresas no sentido de enfrentarem as alterações climáticas durante os meses de temperaturas anormais, evidenciado por uma redução das emissões de carbono. O estudo contribui para a compreensão do comportamento dos investidores no contexto das alterações climáticas, realçando a complexa dinâmica entre os fenómenos climáticos, a sensibilização do público e os mercados financeiros.

Palavras-chave Alterações climáticas, Sensibilização dos investidores, Temperaturas anormais, Catástrofes naturais, Emissões de carbono

Título: Investir num mundo em aquecimento: Um mergulho profundo na consciencialização dos investidores e nos retornos das ações nas cidades europeias

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1. Introduction

The accelerating public awareness of climate-related threats raises the urgency of mitigating climate change. The Paris Agreement on Climate Change in 2015 aimed to limit the rise in the global mean temperature to “well below” 2ºC, in accordance with the recommendations of the Intergovernmental Panel on Climate Change (IPCC). The Paris Agreement was a historic occasion never before seen in the history of climate change discussions due to the great number of participants and the significance of the commitments. Many nations are developing new regulations and establishing long-term goals to reduce greenhouse gas emissions.

The world is facing unprecedented environmental challenges, which are manifesting themselves in the form of abnormal temperatures and an increasing frequency and intensity of natural disasters, a trend that is frequently linked to climate change. The effects of global warming are being felt all over the world, with catastrophic wildfires and severe droughts among the effects.

This research explores the relationship between investors’ awareness of climate risk and stock returns from several perspectives in 32 European cities. First, I study people’s reactions to abnormal temperatures and natural disaster shocks by examining their attention to climate change. My results show that there is no difference in the number of Google Searches for the topic "global warming" during local extreme temperatures or after natural disaster shocks in a particular city. When looking at temperature quartiles at the country level, investors pay less attention to global warming when experiencing both abnormally warm and cool months.

Even though average temperatures have risen significantly over the past few decades in much of the world, investors may find it difficult to recognize long-term rises in these temperatures due to the variability of the climate system. Natural disasters are highly complex events with several possible origins. Consequently, climate change has been considered a phenomenon that is particularly challenging for humans to link actual experiences to abstract notions of climate-change risks.

Next, firms are classified as carbon-intensive firms and lower-intensive firms according to their carbon emissions levels. In fact, I find that there is no relationship between abnormally high temperatures and stock returns in both classifications. Surprisingly, when looking at temperature quartiles, I find that abnormal temperatures have a positive effect on the returns of firms. There is no significant return reversal in the longer term. Additionally, I find that firms are taking actions to mitigate climate change when facing abnormal temperatures by reducing their emissions.

In an alternative specification, I defined the high- and low-emission firms according to their industry and I find that firms reduce their emissions when investors are more aware of climate change. Investors are paying closer attention to global warming, forcing firms to focus on carbon emissions.

Additional tests were done by dividing companies by size and under periods of financial crisis as robustness checks. I find that small firms seem to be more affected by abnormal temperatures and that during crisis periods abnormal temperatures do not affect stock returns, as investors may be more focused on broader macroeconomic factors.

This thesis explores the intricate relationships between public perceptions, climate events and stock returns, contributing to the expanding field of research on climate change and financial markets. These findings suggest that financial goals and sustainably responsible actions must be coordinated in order to successfully handle the challenges brought on by a changing global environment.

The remaining part of the dissertation is organized as follows. A brief overview of previous research on the topic is provided in Section 2. Section 3 describes the data sample. Section 4 contains the methodology used. Section 4 presents the empirical findings. In Section 5 shows additional robustness checks. Finally, Section 6 provides the conclusions on the empirical research.

2. Literature Review

Global warming refers to long-term fluctuations in temperature, precipitation, wind, and other elements of the Earth's climate system usually not visible on a personal level (Belić, 2006). In contrast, the local temperature is more visible, and it is influenced by factors such as global warming. Multiple studies investigate the connection between Natural Disasters and climate change. global warming is predicted to increase the frequency and intensity of Natural Disasters, including heat waves, tropical cyclones, droughts, floods, and landslides (Banholzer et al., 2014). Francis & Vavrus (2012) showed evidence that Arctic amplification can enhance more persistent weather patterns in mid-latitudes and increase the probability of extreme weather events such as drought, flooding, cold spells, and heat waves.

Busse et al. (2015) found that the choice to purchase a car is highly dependent on the weather at the time of purchase because consumers overvalue warm or cold weather vehicle types depending on the weather conditions on that day. Murray et al. (2010) found empirical evidence that weather affects consumer spending, more specifically that increasing exposure to sunlight leads to higher consumer spending.

In this paper, I test peoples' reactions to abnormal local temperatures and Natural Disasters by examining their attention to climate change and stock prices. Previous research indicates that people can perceive and adapt to climate variability and change aspects based on personal observations as well as experience with local weather. After experiencing abnormal temperatures, people perceived it as more common than it is, leading to an overestimation of the frequency of warm days in the past, influencing people's beliefs about climate change (Zaval et al., 2014). Howe et al. (2012) found that individuals who live in places with rising average temperatures are more likely than others to perceive local warming, increasing their concern about the urgency of addressing the problem of climate change. Li et al. (2011) found that respondents who believed the day was warmer than usual also showed a higher willingness to donate money to a global-warming charity. Moreover, experiencing extreme weather events such as floods has also been shown to influence global warming risk perceptions and mitigation behavior among individuals (Spence et al., 2011).

In this paper, the learning process is measured using proxies for attention to evaluate the impact of updated beliefs on stock prices and trading behavior. Experiential learning is my focus, in which individuals learn through their experiences and how these experiences shape their knowledge, skills, and attitudes (Kolb, 1984). After being personally affected by abnormal temperatures and natural disasters, people might search for information on global warming on the internet more frequently. However, investors fail to recognize that abnormal temperatures and natural disasters are an immediate threat and ignore the importance of addressing global warming due to its distant effects and unpredictability.

This study adds to earlier empirical research on how people respond to changes in the weather and other environmental factors. Krueger et al. (2020) found that institutional investors believe that climate risks have financial implications for their portfolio firms' performance, particularly climate-related regulations. Institutional investors already take these risks into account when making investment decisions, and many believe that risk management and engagement are more effective ways to address climate risks than divestment (Kolb, 1984).

Real estate values have already been influenced by issues about climate change among coastal properties. According to Bernstein et al. (2019), expected increases in the sea level risk affect real asset values in coastal areas. They find that coastal homes vulnerable to sea-level rises are priced at 6.6% less relative to similar homes at higher elevations. Although coastal property owners are most concerned about increasing sea levels, there are other ways that climate change could physically affect real estate values. The growing threat of wildfires in several states is another notable issue associated with climate change. Loomis (2004) finds that the value of housing in an unburned town close to a major forest fire has fallen because home buyers and sellers revise their perceptions of fire risk upwards, which reduces house prices.

Academic studies have shown that investors value mandatory disclosure of financial information at the firm level (Greenstone et al., 2006). Matsumura et al. (2013) studied the effects of voluntary public disclosure of emissions on firm value and they found that voluntary disclosure regarding corporate climate change risks mitigates the negative valuation effect of emissions on equity valuations.

Overall, the evidence suggests that investors value increased transparency regarding corporate climate change risks, in particular when such increases in transparency concern large firms, or firms operating in carbon-intensive sectors.

Opinions about investing in green stocks and having a better performance diverge across different literature. Bolton & Kacperczyk (2021) conclude that higher returns on carbon-intensive firms are related to higher emissions as a carbon premium. Pástor et al. (2021) found that stocks of firms with lower total carbon dioxide emissions earn lower returns, implying a lower cost of capital. In related work, Hsu et al. (2022) found that polluting firms earn higher stock returns in the form of risk premiums due to higher exposure to changes in environmental policy. On the other side, Nagy et al. (2015), showed that portfolios that incorporate ESG as an investment signal outperformed the MSCI World Index over the sample period. My work contributes to the ongoing discussion about whether climate risk is priced in stock markets by examining the impact of abnormal temperatures and Natural Disasters on stock prices.

There is identical evidence of climate risk pricing in stock options markets. Ilhan et al. (2020) showed that climate policy uncertainty is priced in the options market and the cost of option protection against variance risk is larger for more carbon-intensive firms.

3. Data

My main database covers 2005-2021 period when climate change was a global phenomenon and there is a considerable number of companies sharing their CO2 emission values covering 32 cities in Europe from STOXX Europe 600 index. Table 1 displays an overview of the variables used in the research.

Weather

Daily weather data was collected from the ERA5 reanalysis data from Copernicus Climate Service. The data includes temperature time-series values in degrees Celsius, for the 1000 most populous cities in the world, from Jan-01-1980 to Sept-30-2020. By identifying the location coordinates, I select the closest city to the address in question. My main test period is between 2005 and 2021, when climate change is a global phenomenon. Considering that temperature data is not available between October 2020 and December 2021, I assume the same growth as in the previous years so that I can extrapolate the final year's temperature. Abnormal temperatures require 10 years of data to calculate so I used 1995 to 2004.

Natural Disasters

The extreme weather events data I study comes from the Emergency Event Database EM-DAT. Disasters are defined by EM-DAT as events or circumstances that exceed local capability and call for a request for external help at the national or international level. Disasters are unplanned, frequently unexpected events that result in substantial damage, devastation, and suffering for people.

Additionally, I focus on the categories of extreme weather that, according to the Intergovernmental Panel on Climate Change, are expected to become more frequent and severe as a result of climate change: Sea level rises, heavy precipitation and floods, heat waves, wildfires and droughts, more tropical storms, and warmer temperatures (IPCC, 2013). However, many of these Disasters may not be severe enough to affect the stock market in the cities being studied. For a Disaster to be considered in the database, at least one of the following conditions must be met: (1) at least ten people killed, (2) damages exceeding $100.000. I followed Baker et al. (2023) and gave a value of one if a Natural Disaster shock occurred and 0 otherwise.

Google Search Volume Index

Google Trends is the data source for internet search activity, more specifically for the investors' attention to global warming and it was captured by a Search Volume Index (DSVI) of the "global warming" search topic. I retrieved the monthly DSVI for each city and country from 2005 to 2021.

Carbon emission

Carbon emission estimates were retrieved from Datastream. I defined high (low) carbon emission firms as firms whose Estimated CO2 Equivalents Emission Total is higher (lower) than the average value of CO2 Equivalents Emission Total of all firms from that country.

Industry

I obtained each firms' SIC codes from Compustat on WRDS and matched these to one of Fama-French 10 industries classification based on SIC codes. The Fama-French-10 industry groups are: Consumer NonDurables (NoDur); Consumer Durables (Durbl); Manufacturing (Manuf); Oil, gas, and Coal Extraction and Products (Enrgy), Computers, Software, and Electronic Equipment (HiTec Business Equipment); Telephone and Television Transmission (Telcm); Wholesale, Retail, and Some Services (Shops); Healthcare, Medical Equipment and Drugs (Hlth) and Others which include Mines, Construction, Construction Materials, Transportation, Hotels, Business Services, Entertainment, Finance. I classified the industries as High-emitters and Low-emitters according to their average value of CO2 Equivalents Emission Total of firms from that industry.

4. Methodology

My goal is to study investor reaction to global warming in times of unusually warm local weather and when natural disasters occur in Europe. The monthly Google Search Volume Index (DSVI) of the topic of global warming in a city serves as a proxy for people's attention to global warming. I followed Da et al. (2011) who approximate people's attention to an asset as the SVI for the ticker of the asset and study its relationship to existing measures of attention.

I break down local temperatures into three distinct components to better understand the learning process. These three parts account for predictable, seasonal, and abnormal trends. In particular, I use the average of the daily average temperatures in my data to get the monthly temperature for each city *i* in month *t*. In line with Choi et al. (2020), abnormal temperatures are defined as follows:

$$\text{Temperature}_{it} = \text{Aver\_Temp}_{it} + \text{Mon\_Temp}_{it} + \text{Ab\_Temp}_{it} \qquad (1)$$

where Aver_Temp_{it} is the average monthly local temperature over the last 120 months in city *i*; Mon_Temp_{it}, which is equal to the average deviation of this month's temperature from the average, is calculated by subtracting Aver_Temp_{it} from the average temperature in city *i* for the same calendar month for the last ten years. Ab_temp_{it} captures whether a city is experiencing abnormal temperatures.

To measure people's reaction to global warming I calculate monthly changes in the Google Search Volume Index (SVI) of the topic of global warming. SVI is the monthly variation in SVI in city *i* in month *t*.

To examine the impact of abnormal local temperatures and natural disasters on Google Search Volume I use the following regression:

$$\text{DSVI}_{it} = \alpha + \beta_1 \text{Ab\_Temp}_{it} + \sigma_m + \delta_t + \epsilon_{it} \qquad (2)$$

where DSVI_{it} is monthly variation in SVI in city *i* in month *t* (from 2005 to 2021) and Ab_Temp_{it} is the abnormal temperature in city *i* in month *t* based on the decomposition in Equation (1). σ_m and δ_t refer to year-fixed effects and country-fixed effects, respectively.

$$\text{DSVI}_{it} = \alpha + \beta_1 \text{Natural\_Disaster}_{it} + \sigma_m + \delta_t + \epsilon_{it} \qquad (3)$$

where DSVI_{it} is monthly variation in SVI in city *i* in month *t* (from 2005 to 2021) and $\text{Natural\_Disaster}_{it}$ is a dummy variable that equals one if a natural disaster shock occurred in city *i* in month *t*. σ_m and δ_t refer to year-fixed effects and country-fixed effects, respectively.

Following that, I analyze if local temperatures and natural disasters impact stock prices, particularly on the diverse reactions in the cross-section of firms with different sensitivities to climate change. Both the long-term and short-term patterns are looked at.

The effect of abnormal temperatures and natural disasters on stock prices can occur in several ways. First, investors can revise their beliefs about climate change and could have done their own valuation of firms. Second, investors might believe that climate change will hurt high-carbon companies' future earnings by limiting their production functions, raising the cost of future emissions, or resulting in tighter emission regulations. Lastly, by understanding the risk of global warming, socially conscious investors can consider not investing in firms that are not climate-friendly, like some investors stay away of sin stocks (Hong & Kacperczyk, 2009).

First, I build two portfolios based on the definitions described in Section 3. Portfolio $EMISSION_i$ is composed of the high carbon emission firms in city i and portfolio $CLEAN_i$ is composed of the low carbon emission firms in city *i*. Then I created a long-short portfolio EMC composed of buying $EMISSION_i$ and selling $CLEAN_i$. All portfolios were constructed using both equal weights and value weights. To capture the relationship between abnormal temperatures in city *i* and stock returns I run the following regression:

$$EMC_{it} = \alpha + \beta_1 \text{Ab\_Temp}_{it} + \sigma_m + \delta_t + \epsilon_{it} \quad (4)$$

where EMC_{it} is the value-weighted or equal-weighted return of the EMC portfolio in city *i* in month *t* (from 2005 to 2021) and Ab_Temp_{it} is the abnormal temperature in city *i* in month *t* based on the decomposition in Equation (1). σ_m and δ_t refer to year-fixed effects and country-fixed effects, respectively.

To capture the relationship between natural disasters in city *i* and stock returns I run the following regression:

$$EMC_{it} = \alpha + \beta_1 \text{Natural\_Disaster}_{it} + \sigma_m + \delta_t + \epsilon_{it} \quad (5)$$

where EMC_{it} is the value-weighted or equal-weighted return of the EMC portfolio in city *i* in month *t* (from 2005 to 2021) and $\text{Natural\_Disaster}_{it}$ is a dummy variable that equals one if a natural disaster shock occurred in city *i* month *t*. σ_m and δ_t refer to year-fixed effects and country-fixed effects, respectively.

I then look at the long-term results following an abnormally warm month by running the following regression:

$$EMC_{1,t+1,t+n} = \alpha + \beta_1 \text{Ab\_Temp}_{it} + \sigma_m + \delta_t + \epsilon_{it} \quad (6)$$

where $n = \{3;\ 6;\ 12\}$ and the returns are measured from month t + 1 to month t + n. σ_m and δ_t refer to year-fixed effects and country-fixed effects, respectively.

Next, I look at the long-term results after a natural disaster shock month by running the following regression:

$$EMC_{1,t+1,t+n} = \alpha + \beta_1 \text{Natural\_Disaster}_{it} + \sigma_m + \delta_t + \epsilon_{it} \quad (7)$$

where $n = \{3;\ 6;\ 12\}$ and the returns are measured from month t + 1 to month t + n. σ_m and δ_t refer to year-fixed effects and country-fixed effects, respectively.

After studying the impact of abnormal local temperatures on portfolios with different levels of carbon emissions, I examined if abnormal local temperatures affect firms' stock returns by running the following regression:

$$\text{Stock Returns}_{it} = \alpha + \beta_1 \text{Ab\_Temp}_{it} + X_{it} + \delta t + \epsilon_{it} \quad (8)$$

where Stock Returns_{it} is the return of firm *i* in month *t* (from 2005 to 2021). δ_t refers to year-fixed effects. I control for firm characteristics in $X_{i,t}$ including Log Total Assets, Leverage and WC/Total Assets. Serial correlation of errors and heteroskedasticity are controlled for by using robust standard errors.

Then, I examined if people's attention to global warming affects firms' stock returns by running the following regression:

$$\text{Stock Returns}_{it} = \alpha + \beta_1 \text{DSVI}_{it} + X_{it} + \sigma_m + \delta_t + \epsilon_{it} \quad (9)$$

After looking at the investor reactions to global warming in the stock market it is relevant to examine if firms are acting to combat climate change by mitigating their emissions. I analyzed whether companies' attention to climate change affects their emissions using the following regression:

$$\text{Emissions}_t = \alpha + \beta_1 \text{DSVI}_{it} + X_{it} + \delta t + \epsilon_{it} \quad (10)$$

To better understand whether companies are also concerned about their emissions levels when they experience abnormal temperatures, I analyzed if abnormal temperatures affect companies' emissions:

$$\text{Emissions}_t = \alpha + \beta_1 \text{Ab\_Temp}_{it} + X_{it} + \delta t + \epsilon_{it} \quad (11)$$

where Emissions_{it} is the estimated total CO_2 and CO_2 Equivalents Emissions in tones per firm i in month t (from 2005 to 2021).

To shed more light on how abnormal temperatures and attention to the issue of global warming affect stock returns and companies' emissions mitigation, I explore the cross-sectoral differences. I re-run the previous four regressions for companies in the two sectors with the highest emissions and then for the two sectors with the lowest emissions, according to the definitions described in Section 2.

5. Empirical Results

The aim of my empirical analysis is to study if people's attention is impacted by local temperatures and Natural Disasters shocks and, if so, how that affects the stock price of local companies and the trading behavior of investors.

5.1 People's attention and local temperatures

Table 2 investigates whether higher abnormal local temperatures are related to an increased attention to the topic of global warming by running Equation (2).

Table 2. Google Search volume for global warming and abnormal temperatures
This Table reports the results of analyses on the effect of abnormal temperatures on the search volume of the topic of "global warming" on google. DSVI (City) is the monthly change of google's search volume index (DSVI) of the topic "global warming". Aver_Temp is the average monthly temperature (in Celsius degrees) of the exchange's city over the previous 120 months. Mon_Temp is the city's average temperature in the same month of the year over the previous 10 years minus Aver_Temp. Ab_Temp is the city's temperature in this month minus Aver_Temp and Mon_Temp. This Table represents the result of regressing DSVI (City) (Columns 1 and 2) and DSVI (Country) (Columns 3 and 4) on city-level temperature measures. For each exchange city, months are sorted into quartiles based on Ab_Temp. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. T-statistics are shown in parentheses. ∗∗∗, ∗∗ and ∗ represent 1%, 5%, and 10% significance levels, respectively.

VARIABLES	(1) DSVI (City)	(2) DSVI (City)	(3) DSVI (Country)	(4) DSVI (Country)
Ab_Temp	0.002		0.004	
	(0.121)		(0.387)	
Ab_Temp_Q1		-0.362		-1.342***
		(-0.578)		(-2.824)
Ab_Temp_Q2		0.055		-1.462***
		(0.089)		(-3.101)
Ab_Temp_Q3		-0.401		-1.677***
		(-0.654)		(-3.603)
Ab_Temp_Q4		-0.777		-1.373***
		(-1.270)		(-2.953)
Constant	0.437	0.802	1.031*	2.329***
	(0.557)	(0.892)	(1.725)	(3.409)
Observations	6,528	6,528	6,528	6,528
Year FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Adjusted R-squared	-0.00562	-0.00570	-0.000546	0.00144

The coefficient of Ab_Temp has no statistical significance (t-stat = 0.121) in Model (1), indicating that there is no change in people's attention to global warming when experiencing an abnormally high temperature.

In Model (2), I used Ab_Temp in city *i* to rank all months into quartiles, and I used these quartile dummies in the regression rather than Ab_Temp. The coefficients of abnormal temperature quartiles do not show a pattern and are statistically insignificant. These results show that there is no differential in people's reaction to global warming across the temperature quartiles at a city level.

Then I run all the regressions again, changing the DSVI for city *i* to the DSVI for the country. The overall statistics of the two DSVIs are identical, as seen by Table 2. Models (3) and (4) present the results for attention to global warming at a country level.

Model (3) shows that higher abnormal temperature has no relation to Google Search volume by country on the topic of global warming (t-stat 0.387). When looking at temperature quartiles the coefficients are all negatively significant which reveals that investors pay less attention to global warming when experiencing both abnormally warmest and coolest months. A possible explanation could be that investors could not perceive abnormal temperatures as an imminent threat and discount the importance of addressing global warming due to distant consequences and uncertainty. Usually, I prioritize short-term experiences over long-term concerns. Warmer temperatures might lead individuals to focus on the weather's immediate benefits rather than on the longer-term effects of climate change.

5.2 Local temperatures and stock returns across different emissions levels

Next, I investigate if abnormal local weather has an impact on stock returns, looking at a cross-section of firms with varying CO2 emissions.

Table 3. Emission-minus-clean portfolio return and abnormal temperatures

Carbon emission estimates were retrieved from Datastream. I defined high (low) carbon emission firms as firms whose Estimated CO2 Equivalents Emission Total is higher (lower) than the average value of CO2 Equivalents Emission Total of all firms from that country. At the beginning of month *t*, EMISSION and CLEAN portfolios are formed based on firms' carbon emissions. High carbon emission firms (EMISSION) are defined as firms whose Estimated CO2 Equivalents Emission Total is higher than the average value of CO2 Equivalents Emission Total of all firms from that country. Low carbon emission firms (CLEAN) are defined as firms whose Estimated CO2 Equivalents Emission Total is lower than the average value of CO2 Equivalents Emission Total of all firms from that country. Portfolio return (as a percentage) equals the average adjusted return of stocks at month *t*, equal-weighted or value-weighted. EMC equals EMISSION minus CLEAN. Panel A reports the results of regressions of EMC on abnormal temperature variables using equal-weighted portfolio returns, and panel B uses value-weighted returns. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. T-statistics are shown in parentheses. ∗∗∗, ∗∗ _and ∗ _represent 1%, 5%, and 10% significance levels, respectively.

Panel A - Equal-weighted EMC returns

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	EMC	EMC	CLEAN	CLEAN	EMISSION	EMISSION
Ab_Temp	-0.007		0.002		-0.003	
	(-1.076)		(0.410)		(-0.443)	
Ab_Temp_Q1		0.643**		1.535***		2.178***
		(2.028)		(5.218)		(6.890)
Ab_Temp_Q2		0.678**		1.082***		1.760***
		(2.154)		(3.707)		(5.611)
Ab_Temp_Q3		0.408		1.307***		1.715***
		(1.314)		(4.535)		(5.538)
Ab_Temp_Q4		0.469		0.437		0.906***
		(1.512)		(1.519)		(2.930)
Constant	-0.299	-0.777*	2.636***	1.691***	0.751***	0.914**
	(-0.750)	(-1.704)	(7.114)	(3.999)	(7.666)	(2.012)
Observations	6,528	6,528	6,528	6,528	6,528	6,528
Year FE	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES
Adjusted R-squared	-0.00398	-0.00373	0.0265	0.0317	-0.00490	0.0289

Panel B - Value-weighted EMC returns

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	EMC	EMC	CLEAN	CLEAN	EMISSION	EMISSION
Ab_Temp	-0.009		0.004		-0.005	
	(-1.288)		(0.687)		(-0.706)	
Ab_Temp_Q1		0.722**		1.497***		2.219***
		(2.101)		(4.905)		(6.781)
Ab_Temp_Q2		0.742**		1.098***		1.840***
		(2.177)		(3.625)		(5.667)
Ab_Temp_Q3		0.502		1.268***		1.770***
		(1.491)		(4.243)		(5.523)
Ab_Temp_Q4		0.454		0.578*		1.031***
		(1.351)		(1.935)		(3.223)
Constant	-0.128	-0.652	2.605***	1.638***	2.478***	0.986**
	(-0.296)	(-1.321)	(6.781)	(3.734)	(6.003)	(2.097)
Observations	6,528	6,528	6,528	6,528	6,528	6,528
Year FE	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES
Adjusted R-squared	-0.00395	-0.00374	0.0226	0.0267	0.0198	0.0278

The results for Equation (4) are shown in Panels A (for equal-weighted portfolios) and B (for value-weighted portfolios) of Table 3. In Model (1) of panel A, the coefficient is not statistically significant with a t-stat of -1.076, which means that there is no relationship between high abnormal temperatures and EMC returns. Model (2) uses quartile dummies for abnormal temperatures instead of Ab_Temp. In the city's coolest quartiles (1 and 2), EMC earns significantly higher returns than in the warmest quartiles. There is an increase in returns of 0.64% (t-stat = 2.028) with a change from temperature quintile 4 (warmest) to quintile 1 (coolest). Models (3) and (4) study CLEAN portfolio returns. Although the abnormal temperature coefficient is insignificant with a t-stat = -0.443, all temperature quartiles are statistically significant and positive, meaning that unusual temperatures have a positive effect on the returns of firms with low emissions. The results for EMISSION portfolio are reported in Models (5) and (6) and are generally similar to the CLEAN portfolio. Looking at atypical local weather, it is observed that the two portfolios have opposite effects on EMC returns, but the EMISSION portfolio has more influence, attributable to a larger coefficient of 2.219, consequently leading to heightened EMC returns. Panel B shows the value-weighted returns, and the results are equivalent to those of the equal-weighted portfolios.

The long-term performance of the equal-weighted EMC portfolio after an abnormal local month using Equation (6). If the coefficient is negative or zero, it indicates a slow updating of beliefs, meaning that investors with short attention spans tend to ignore climate risk, but they do notice it when responding to weather events that capture their attention. In contrast, a positive coefficient suggests that some of the belief update in month t is an overreaction due to the reversal of the prior pricing pattern.

Table 4. Long-term EMC returns subsequent to abnormal temperature

The Table reports the results of regressions of $EMC_{t+1,t+3}$, $EMC_{t+1,t+6}$, and $EMC_{t+1,t+12}$ on abnormal temperature variables at month t. All EMC returns are calculated using the equal-weighted average of adjusted returns. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. T-statistics are shown in parentheses. $***$, $**$ _and $*$ _represent 1%, 5%, and 10% significance levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	$EMC_{t+1,t+3}$		$EMC_{t+1,t+6}$		$EMC_{t+1,t+12}$	
Ab_Temp	0.004		0.000		-0.000	
	(0.972)		(0.072)		(-0.145)	
Ab_Temp_Q1		-0.007		-0.077		-0.016
		(-0.035)		(-0.596)		(-0.178)
Ab_Temp_Q2		-0.050		-0.165		0.048
		(-0.274)		(-1.278)		(0.518)
Ab_Temp_Q3		-0.019		-0.197		-0.002
		(-0.107)		(-1.549)		(-0.024)
Ab_Temp_Q4		-0.073		-0.216*		-0.007
		(-0.403)		(-1.702)		(-0.077)
Constant	-0.214	-0.180	-0.155	-0.007	-0.091	-0.093
	(-0.921)	(-0.678)	(-0.948)	(-0.037)	(-0.780)	(-0.700)
Observations	6,528	6,528	6,528	6,528	6,528	6,528
Year FE	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES
Adjusted R-squared	0.00161	0.00104	0.0108	0.0109	0.0260	0.0256

Results are shown in Table 4. The coefficients of Ab_Temp are not statistically significant, as Models (1), (3), and (5) demonstrate. Columns 2, 4, and 6's temperature quartile coefficients do not exhibit a regular pattern and are typically statistically insignificant. These findings suggest that there is no strong continuation or reversal of returns in the 3 to 12 months after month t.

5.3 Natural Disasters impact on people's attention and stock returns

Table 5 presents the results of Equation (3) where I study the possible link between investors' attention to climate risk and Natural Disaster shocks and explore the resulting impact on the stock returns and trading patterns.

Table 5. Google Search volume for global warming and Natural Disasters shocks

This Table reports the results of analyses on the effect of abnormal temperatures on the search volume of the topic of "global warming" on google. Panel A presents summary statistics of the variables. DSVI (City) is the monthly change of google's search volume index (DSVI) of the topic "global warming". Natural_Disaster is a dummy variable that equals one if a Natural Disaster shock occurred in city *i* in month *t*. This Table represents the result of regressing DSVI (City) (Column 1) and DSVI (Country) (Column 2) on Natural Disasters shocks. Year-fixed effects and country-fixed effects are included in all regressions. T-statistics are shown in parentheses. ∗∗∗, ∗∗ and ∗ represent 1%, 5%, and 10% significance levels, respectively.

VARIABLES	(1) DSVI (City)	(2) DSVI (Country)
Natural_Disaster	0.336	-0.136
	(1.530)	(1.163)
Constant	0.429	1.035*
	(0.787)	(0.598)
Observations	6,528	6,528
R-squared	0.002	0.007
Number of City1	32	32
Year FE	YES	YES
Country FE	YES	YES
Adjusted R-squared	-0.00561	-0.000567

The results show evidence that people's attention does not change with Natural Disasters shocks. Natural Disasters tend to be complex events with numerous underlying causes. Therefore, establishing a direct connection between a specific disaster and climate change may be a considerable challenge for individuals. Long-term trends may have a greater impact on beliefs about climate change than unpredictable occurrences such as isolated Natural Disasters. Individuals may regard these occurrences as sporadic incidences that do not necessarily influence their perceptions of larger trends in climate change.

Table 6. Emission-minus-clean portfolio return and Natural Disasters shocks

At the beginning of month t, EMISSION and CLEAN portfolios are formed based on firms' carbon emissions. Portfolio return (as a percentage) equals the average adjusted return of stocks at month *t*, equal-weighted or value-weighted. EMC equals EMISSION minus CLEAN. Panel A reports the results of regressions of EMC on Natural Disasters shocks using equal-weighted portfolio returns, and panel B uses value-weighted returns. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. T-statistics are shown in parentheses. ∗∗∗, ∗∗ and ∗ represent 1%, 5%, and 10% significance levels, respectively.

Panel A - Equal-weighted EMC returns

VARIABLES	(1) EMC	(2) CLEAN	(3) EMISSION
Natural_Disaster	0.011	-0.005	0.006
	(1.397)	(-0.738)	(0.710)
Constant	-0.003	0.026***	0.023***
	(-0.820)	(7.142)	(5.816)
Observations	6,528	6,528	6,528
Year FE	YES	YES	YES
Country FE	YES	YES	YES
Adjusted R-squared	-0.00386	0.0266	0.0205

Panel B - Value-weighted EMC returns

VARIABLES	(1) EMC	(2) CLEAN	(3) EMISSION
Natural_Disaster	0.010	-0.001	0.009
	(1.193)	(-0.158)	(1.100)
Constant	-0.002	0.026***	0.025***
	(-0.356)	(6.780)	(5.940)
Observations	6,528	6,528	6,528
R-squared	0.003	0.030	0.027
Number of City1	32	32	32
Year FE	YES	YES	YES
Country FE	YES	YES	YES
Adjusted R-squared	-0.00399	0.0225	0.0199

Table 7. Long-term EMC returns after Natural Disasters

The Table reports the results of regressions of $EMC_{t+1,t+3}$, $EMC_{t+1,t+6}$, and $EMC_{t+1,t+12}$ on Natural Disasters shocks variables at month t. All EMC returns are calculated using the equal-weighted average of adjusted returns. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. T-statistics are shown in parentheses. $***$, $**$ _and $*$ _represent 1%, 5%, and 10% significance levels, respectively.

VARIABLES	(1) $EMC_{t+1,t+3}$	(2) $EMC_{t+1,t+6}$	(3) $EMC_{t+1,t+12}$
Natural_Disaster	0.002	-0.002	-0.002
	(0.359)	(-0.510)	(-0.683)
Constant	-0.002	-0.002	-0.001
	(-0.938)	(-0.921)	(-0.744)
Observations	6,527	6,527	6,527
Year FE	YES	YES	YES
Country FE	YES	YES	YES
Adjusted R-squared	0.00149	0.0108	0.0260

Tables 6 and 7 present the results of Equations (5) and (7) to examine the impact of Natural Disaster shocks on short- and long-term stock returns, respectively. The coefficients of Natural_Disaster are insignificant meaning that Natural Disasters and stock returns are not related.

5.4 Local temperatures and stock returns

I then conducted an analysis without making any distinctions based on emission levels to assess the impact of abnormal local temperatures on firms' stock returns by running Equation (8). Table 8 shows the summary statistics of, as well as those of stock returns, Ab_Temp, DSVI (City), DSVI (Country) and emissions.

Table 9. Abnormal temperatures and stock returns

This Table reports the results of analyses on the effect of abnormal temperatures on stock returns. See Table 2 for definitions of Ab_Temp and Ab_Temp_Q1-Q4. Stock returns (as a percentage) is the return of stocks at month t. This Table represents the result of regressing city-level abnormal temperature measures on stock returns. For each exchange city, months are sorted into quartiles based on Ab_Temp. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. I control for firm characteristics in Xi,t including Log Total Assets, Log Leverage and Log WC/Total Assets. Serial correlation of errors and heteroskedasticity are controlled for by using robust standard errors. T-statistics are shown in parentheses. ***, ** and * represent 1%, 5%, and 10% significance levels, respectively.

VARIABLES	(1) Stock returns	(2) Stock returns
Ab_Temp	0.029	
	(0.260)	
Ab_Temp_Q1		-0.231
		(-1.256)
Ab_Temp_Q2		-0.275
		(-1.442)
Ab_Temp_Q3		-0.350**
		(-2.073)
Ab_Temp_Q4		-0.367**
		(-2.015)
TOTAL ASSETS	-0.000	-0.000
	(-0.831)	(-0.788)
WC/ASSETS	-1.055	-1.047
	(-1.411)	(-1.407)
LEVERAGE	0.535	0.506
	(1.222)	(1.167)
Ab_Temp	0.029	
	(0.260)	
Constant	1.773	2.311***
	(1.619)	(11.717)
Observations	43,030	43,030
Year FE	YES	YES
Adjusted R-squared	0.0392	0.0392

Table 9 offers the results of this analysis. Model (1) suggests that a higher abnormal temperature is not associated with changes in stock returns. In Model (2), I substitute Ab_Temp with the quartile dummies based on the city's abnormal temperature. As we increase the temperature quartile, stock returns decline more, with statistically significant underperformance in the warmest quintile. Neither of my results are consistent with my stock returns results in Section 5.2.

5.5 People's attention and stock returns

Table 10 presents the results of Equation (9) where I examine the influence of Google Search activity about global warming on stock returns.

Table 10. Attention to global warming and stock returns

This Table reports the results of analyses on the effect of attention to the topic of global warming on stock returns. See Table 2 for definitions DSVI (City) and DSVI (Country). Stock returns (as a percentage) is the return of stocks at month *t* for firm *j*. This Table represents the result of regressing DSVI (City) (Column 1) and DSVI (Country) (Column 2) on stock returns. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. I control for firm characteristics in Xi,t including Log Total Assets, Log Leverage and Log WC/Total Assets. Serial correlation of errors and heteroskedasticity are controlled for by using robust standard errors. T-statistics are shown in parentheses. ∗∗∗, ∗∗ and ∗ represent 1%, 5%, and 10% significance levels, respectively.

VARIABLES	(1) Stock returns	(2) Stock returns
DSVI (City)	0.008***	
	(2.967)	
DSVI (Country)		0.005*
		(1.695)
TOTAL ASSETS	-0.000	-0.000
	(-0.826)	(-0.823)
WC/ASSETS	-1.044	-1.054
	(-1.397)	(-1.408)
LEVERAGE	0.530	0.534
	(1.214)	(1.220)
Constant	2.054***	2.048***
	(16.527)	(16.453)
Observations	43,030	43,030
R-squared	0.040	0.040
Number of Name1	218	218
Year FE	YES	YES

In Table 10, Model (1) shows evidence that the attention to global warming by city has a statistically significant impact on stock returns, denoted by a coefficient of 0.008 and a t-statistic of 2.967. In contrast, the attention to global warming on a country level represented in Model (2) demonstrates a non-significant effect on stock returns, indicated by a coefficient of 0.005 with a lower t-statistic of 1.695. These results indicate city-specific factors have a greater impact on changes in stock returns than do those at the country level.

5.6 Local temperatures and firms' emissions

Table 11. Abnormal temperatures and CO2 emissions

This Table reports the results of analyses on the effect of abnormal temperatures on carbon emissions. Carbon emission estimates were retrieved from Datastream. See Table 2 for definitions of Ab_Temp and Ab_Temp_Q1-Q4. Emissions is the Log amount of Estimated CO2 Equivalents Emission Total (in tonnes) in month *t* for firm *j*. This Table represents the result of regressing city-level abnormal temperature measures on carbon emissions. For each exchange city, months are sorted into quartiles based on Ab_Temp. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. I control for firm characteristics in $X_{i,t}$ including Log Total Assets, Log Leverage and Log WC/Total Assets. Serial correlation of errors and heteroskedasticity are controlled for by using robust standard errors. T-statistics are shown in parentheses. ∗∗∗, ∗∗ and ∗ represent 1%, 5%, and 10% significance levels, respectively.

VARIABLES	(1) Emissions	(2) Emissions
Ab_Temp	-0.005**	
	(-2.244)	
Ab_Temp_Q1		0.006
		(0.885)
Ab_Temp_Q2		0.009
		(1.198)
Ab_Temp_Q3		-0.005
		(-1.232)
Ab_Temp_Q4		-0.001
		(-0.236)
TOTAL ASSETS	-0.000	-0.000
	(-1.174)	(-0.907)
WC/ASSETS	-0.005	-0.006
	(-0.130)	(-0.159)
LEVERAGE	-0.026	-0.026
	(-0.912)	(-0.908)
Ab_Temp	-0.005**	
	(-2.244)	
Constant	8.844***	8.793***
	(430.106)	(1,392.639)
Observations	41,241	41,241
Year FE	YES	YES
Adjusted R-squared	0.467	0.468

In Table 11, shows the results of running Equation (11). Model (1) shows that experiencing a higher abnormal temperature is associated with significantly lower firm emissions (t-stat = -2.244). Companies may perceive higher abnormal temperatures as a "wake-up" call on climate-related risks. Firms are increasingly aware of their social responsibility, and to improve their reputation, they take action to fight climate change.

5.7 People's attention and firms' emissions

Table 12. Abnormal temperatures and CO2 emissions

This Table reports the results of analyses on the effect of abnormal temperatures on carbon emissions. Carbon emission estimates were retrieved from Datastream. See Table 2 for definitions of DSVI (Country) and DSVI (City). EMISSIONS is the Log amount of Estimated CO2 Equivalents Emission Total (in tonnes) in month *t* for firm *j*. This Table represents the result of regressing DSVI on carbon emissions. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. I control for firm characteristics in $X_{i,t}$ including Log Total Assets, Log Leverage and Log WC/Total Assets. Serial correlation of errors and heteroskedasticity are controlled for by using robust standard errors. T-statistics are shown in parentheses. ∗∗∗, ∗∗ and ∗ represent 1%, 5%, and 10% significance levels, respectively.

VARIABLES	(1) Emissions	(2) Emissions
DSVI (City)	-0.000	
	(-0.410)	
DSVI (Country)		-0.000
		(-0.478)
TOTAL ASSETS	-0.000	-0.000
	(-1.221)	(-1.221)
WC/ASSETS	-0.005	-0.005
	(-0.134)	(-0.134)
LEVERAGE	-0.026	-0.026
	(-0.914)	(-0.913)
Constant	8.799***	8.799***
	(3,586.362)	(3,585.940)
Observations	41,241	41,241
Year FE	YES	YES
Adjusted R-squared	0.467	0.467

Table 12 shows the results of Equation (10) where I examined if the investor's attention to global warming has an impact on firms' emission levels. On both city and country levels, the coefficient is not significant meaning that there is no direct impact of investors' attention to global warming on firms' emission levels. This could be because there may be a delay in shifts in investor attitude and focus to have a noticeable impact on the way businesses react. The observable impact on emission levels may be restricted if the research period is very short or if investors' concerns have not lasted over an extended period.

6. Robustness tests

To ensure the validity of the results presented in this paper, some robustness tests are run. I conduct subsample regressions to examine the abnormal temperatures and stock returns.

6.1 In-depth industry analysis

I analyzed the differences between firms from low-emitter and high-emitter industries. Abnormal temperatures are not associated with stock returns in both cases as shown in Table 13. In contrast, attention to the topic of global warming has a different impact on stock returns according to the firm's industry as shown in Table 14. The attention to global warming at a country level only has a positive impact on changes in stock returns for low-emitter industries, but in both cases when looking at results at a city level the values are significantly positive, consistent with my results in Section 5.5. Table 15, Model (1) and (3) show that when experiencing abnormal temperatures, neither firms within low-emitter industries nor high-emission industries exhibit a reduction in their emission levels, not consistent with Section 5.6. Surprisingly, in Table 16, Model (4) reveals that firms within high-emitter industries reduce their emissions when investors pay more attention to global warming at a country level. In these industries, firms tend to reduce carbon emissions primarily when investors are more aware of global warming due to the increasing significance of risks and sustainability concerns growing in investment decision-making.

Table 13. Abnormal temperatures and stock returns by industry levels of carbon emissions

This Table reports the results of analyses on the effect of abnormal temperatures on stock returns for low-emitter industries and high-emitter industries. I classified the industries as High emitters and Low emitters according to their average value of CO2 Equivalents Emission Total of firms from that industry. See Table 2 for definitions of Ab_Temp and Ab_Temp_Q1-Q4. Stock returns (as a percentage) is the return of stocks at month *t*. Panel B represents the result of regressing city-level abnormal temperature measures on stock returns. For each exchange city, months are sorted into quartiles based on Ab_Temp. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. I control for firm characteristics in $X_{i,t}$ including Log Total Assets, Log Leverage and Log WC/Total Assets. Serial correlation of errors and heteroskedasticity are controlled for by using robust standard errors. T-statistics are shown in parentheses. ∗∗∗, ∗∗ and ∗ represent 1%, 5%, and 10% significance levels, respectively.

	Low emitters		High emitters	
	(1)	(2)	(3)	(4)
VARIABLES	Stock returns	Stock returns	Stock returns	Stock returns
Ab_Temp	-0.300		0.158	
	(-0.970)		(1.407)	
Ab_Temp_Q1		-0.170		-0.758
		(-0.645)		(-1.239)
Ab_Temp_Q2		0.062		-0.661
		(0.235)		(-1.118)
Ab_Temp_Q3		-0.252		-1.046*
		(-0.993)		(-2.093)
Ab_Temp_Q4		-0.235		-0.483
		(-0.917)		(-0.854)
TOTAL ASSETS	-0.000	-0.000	-0.000	-0.000
	(-0.026)	(-0.160)	(-0.719)	(-0.296)
WC/ASSETS	-0.862	-0.904	-3.589	-4.158
	(-0.604)	(-0.650)	(-1.112)	(-1.283)
LEVERAGE	0.125	0.121	0.210	0.264
	(0.176)	(0.173)	(0.198)	(0.239)
Constant	4.893	2.031***	0.619	2.918***
	(1.588)	(7.438)	(0.540)	(5.203)
Observations	19,547	19,547	4,056	4,056
Year FE	YES	YES	YES	YES
Adjusted R-squared	0.0390	0.0390	0.0281	0.0280

Table 14. Attention to global warming and stock returns by industry levels of carbon emissions

This Table reports the results of analyses on the effect of attention to the topic of global warming on stock returns for low-emitter industries and high-emitter industries. See Table 2 for definitions DSVI (City) and DSVI (Country). Stock returns (as a percentage) is the return of stocks at month *t* for firm *j*. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. I control for firm characteristics in $X_{i,t}$ including Log Total Assets, Log Leverage and Log WC/Total Assets. Serial correlation of errors and heteroskedasticity are controlled for by using robust standard errors. T-statistics are shown in parentheses. ∗∗∗, ∗∗ and ∗ represent 1%, 5%, and 10% significance levels, respectively.

	Low emitters		High emitters	
	(1)	(2)	(3)	(4)
VARIABLES	Stock returns	Stock returns	Stock returns	Stock returns
DSVI (City)	0.008**		0.015*	
	(2.006)		(2.068)	
DSVI (Country)		0.009**		0.003
		(2.033)		(0.331)
TOTAL ASSETS	-0.000	-0.000	-0.000	-0.000
	(-0.200)	(-0.199)	(-0.728)	(-0.729)
WC/ASSETS	-0.869	-0.872	-3.521	-3.537
	(-0.613)	(-0.614)	(-1.087)	(-1.091)
LEVERAGE	0.118	0.117	0.188	0.198
	(0.167)	(0.165)	(0.178)	(0.186)
Constant	1.910***	1.897***	2.278***	2.300***
	(11.617)	(11.562)	(6.781)	(6.624)
Observations	19,547	19,547	4,056	4,056
Year FE	YES	YES	YES	YES
Adjusted R-squared	0.0391	0.0391	0.0286	0.0280

Table 15. Abnormal temperatures and carbon emissions by industry levels of carbon emissions

This Table reports the results of analyses on the effect of attention to global warming on carbon emissions for low-emitter industries and high-emitter industries. I classified the industries as High emitters and Low emitters according to their average value of CO2 Equivalents Emission Total of firms from that industry. See Table 2 for definitions of Ab_Temp and Ab_Temp_Q1-Q4. Emissions is the Log amount of Estimated CO2 Equivalents Emission Total (in tonnes) in month *t* for firm *j*. Panel B represents the result of regressing city-level abnormal temperature measures on stock returns. For each exchange city, months are sorted into quartiles based on Ab_Temp. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. I control for firm characteristics in $X_{i,t}$ including Log Total Assets, Log Leverage and Log WC/Total Assets. Serial correlation of errors and heteroskedasticity are controlled for by using robust standard errors. T-statistics are shown in parentheses. ∗∗∗, ∗∗ and ∗ represent 1%, 5%, and 10% significance levels, respectively.

	Low emitters		High emitters	
	(1)	(2)	(1)	(2)
VARIABLES	Emissions	Emissions	Emissions	Emissions
Ab_Temp	-0.008		0.000	
	(-1.236)		(0.077)	
Ab_Temp_Q1		0.005		-0.014
		(1.085)		(-1.042)
Ab_Temp_Q2		0.008*		-0.011
		(1.785)		(-1.053)
Ab_Temp_Q3		-0.002		0.024**
		(-0.968)		(2.564)
Ab_Temp_Q4		0.002		0.003
		(1.290)		(0.758)
TOTAL ASSETS	0.000	0.000	-0.000**	-0.000
	(0.154)	(0.144)	(-2.119)	(-1.488)
WC/ASSETS	-0.034	-0.034	0.060	0.061
	(-1.238)	(-1.249)	(1.393)	(1.419)
LEVERAGE	0.005	0.005	-0.032	-0.033
	(0.680)	(0.687)	(-0.962)	(-1.000)
Constant	8.862***	8.775***	8.779***	8.782***
	(135.355)	(1,877.982)	(244.589)	(1,735.306)
Observations	19,462	19,462	3,840	3,840
Year FE	YES	YES	YES	YES
Adjusted R-squared	0.920	0.920	0.752	0.756

Table 16. Attention to global warming and carbon emissions by industry levels of carbon emissions

This Table reports the results of analyses on the effect of attention to global warming on carbon emissions for low-emitter industries and high-emitter industries. Carbon emission estimates were retrieved from Datastream. See Table 2 for definitions of DSVI (Country) and DSVI (City). EMISSIONS is the Log amount of Estimated CO2 Equivalents Emission Total (in tonnes) in month *t* for firm *j*. Panel B represents the result of regressing DSVI on carbon emissions. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. I control for firm characteristics in $X_{i,t}$ including Log Total Assets, Log Leverage and Log WC/Total Assets. Serial correlation of errors and heteroskedasticity are controlled for by using robust standard errors. T-statistics are shown in parentheses. ***, ** and * represent 1%, 5%, and 10% significance levels, respectively.

	Low emitters		High emitters	
VARIABLES	(1) Emissions	(2) Emissions	(1) Emissions	(2) Emissions
DSVI (City)	0.000		-0.000	
	(0.168)		(-1.386)	
DSVI (Country)		0.000		-0.000***
		(0.940)		(-2.927)
TOTAL ASSETS	-0.000	-0.000	-0.000**	-0.000**
	(-0.792)	(-0.791)	(-2.147)	(-2.145)
WC/ASSETS	-0.034	-0.034	0.060	0.060
	(-1.242)	(-1.241)	(1.398)	(1.397)
LEVERAGE	0.005	0.005	-0.032	-0.032
	(0.664)	(0.663)	(-0.960)	(-0.960)
Constant	8.781***	8.781***	8.781***	8.781***
	(5,888.050)	(5,900.066)	(2,983.082)	(2,980.312)
Observations	19,462	19,462	3,840	3,840
Year FE	YES	YES	YES	YES
Adjusted R-squared	0.920	0.920	0.752	0.752

6.2 Robustness to Firm Size

First, I split my dataset based on market capitalization into three categories: small (lowest 20%), medium (20 to 80% percentile), and large companies (above 20%) to see if atypical temperatures had varied effects on the returns of portfolios with firms of different sizes.

Table 17. Abnormal temperatures and stock returns by firms' size

This Table reports the results of analyses on the effect of abnormal temperatures on stock returns for small, medium and large firms. I classified the companies as small, medium, and according to their market capitalization: small (lowest 20%), medium (20 to 80% percentile), and large companies (above 20%). See Table 2 for definitions of Ab_Temp and Ab_Temp_Q1-Q4. Stock returns (as a percentage) is the return of stocks at month *t*. Panel B represents the result of regressing city-level abnormal temperature measures on stock returns. For each exchange city, months are sorted into quartiles based on Ab_Temp. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. I control for firm characteristics in $X_{i,t}$ including Log Total Assets, Log Leverage and Log WC/Total Assets. Serial correlation of errors and heteroskedasticity are controlled for by using robust standard errors. T-statistics are shown in parentheses. ∗∗∗, ∗∗ and ∗ represent 1%, 5%, and 10% significance levels, respectively.

	Small		Medium		Large	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Stock returns	Stock returns	Stock returns	Stock returns	Stock returns	Stock returns
Ab_Temp	1.080***		-0.251		-0.081	
	(2.842)		(-1.632)		(-0.593)	
Ab_Temp_Q1		0.282		0.442**		0.656
		(0.763)		(2.282)		(1.506)
Ab_Temp_Q2		-0.694**		0.449**		1.351***
		(-2.122)		(2.335)		(3.494)
Ab_Temp_Q3		-0.586*		0.658***		1.006**
		(-1.956)		(3.349)		(2.530)
Ab_Temp_Q4		1.339***		0.471**		-0.187
		(4.878)		(2.425)		(-0.577)
TOTAL ASSETS	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(-0.458)	(-0.316)	(-0.688)	(-0.764)	(-0.710)	(-0.675)
WC ASSETS	-0.346	-0.223	-2.849**	-2.834**	3.787	3.781
	(-0.233)	(-0.151)	(-2.377)	(-2.352)	(1.465)	(1.448)
LEVERAGE	-0.602	-0.674	0.742	0.768	-0.522	-0.433
	(-0.823)	(-0.943)	(1.200)	(1.234)	(-0.446)	(-0.365)
Constant	-8.904**	1.268***	4.716***	1.808***	2.622*	1.127***
	(-2.414)	(2.848)	(3.109)	(7.872)	(1.907)	(2.810)
Observations	8,687	8,687	25,645	25,645	8,698	8,698
Year FE	YES	YES	YES	YES	YES	YES
Adjusted R-squared	0.0269	0.0329	0.0594	0.0596	0.165	0.166

In Table 17, I report the results of how abnormal temperatures have different impacts on firms' stock returns according to firm size. Small firms seem to be more affected by abnormal temperatures and medium and large firms are most positively affected by temperatures in the second and third quartiles. Small firms are expected to increase stock returns in periods of abnormal temperatures, but when looking into the quartiles there is not a clear pattern. Interestingly, I find that while stock returns decrease in response to second and third quartile abnormal temperatures, they increase in response to upper quartile abnormal temperatures.

Table 18. Attention to global warming and stock returns by firms' size

This Table reports the results of analyses on the effect of attention to the topic of global warming on stock returns for small, medium and large firms. I classified the companies as small, medium, and according to their market capitalization: small (lowest 20%), medium (20 to 80% percentile), and large companies (above 20%). See Table 2 for definitions DSVI (City) and DSVI (Country). Stock returns (as a percentage) is the return of stocks at month *t* for firm *j*. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. I control for firm characteristics in $X_{i,t}$ including Log Total Assets, Log Leverage and Log WC/Total Assets. Serial correlation of errors and heteroskedasticity are controlled for by using robust standard errors. T-statistics are shown in parentheses. ∗∗∗, ∗∗ and ∗ represent 1%, 5%, and 10% significance levels, respectively.

	Small		Medium		Large	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Stock returns	Stock returns	Stock returns	Stock returns	Stock returns	Stock returns
DSVI (City)	0.019***		0.004		0.014*	
	(3.391)		(1.510)		(1.806)	
DSVI (Country)		0.031***		-0.004		0.021**
		(5.108)		(-1.185)		(2.469)
TOTAL ASSETS	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(-0.332)	(-0.262)	(-0.769)	(-0.770)	(-0.705)	(-0.717)
WC ASSETS	-0.360	-0.387	-2.843**	-2.857**	3.775	3.770
	(-0.244)	(-0.263)	(-2.373)	(-2.385)	(1.460)	(1.458)
LEVERAGE	-0.574	-0.566	0.738	0.744	-0.535	-0.528
	(-0.784)	(-0.773)	(1.192)	(1.201)	(-0.457)	(-0.452)
Constant	1.559***	1.732***	2.281***	2.293***	1.848***	1.928***
	(5.098)	(5.589)	(15.168)	(15.270)	(6.714)	(6.843)
Observations	8,687	8,687	25,645	25,645	8,698	8,698
Year FE	YES	YES	YES	YES	YES	YES
Adjusted R-squared	0.0275	0.0283	0.0594	0.0593	0.165	0.165

Table 18 suggests that increased attention to the topic of global warming has a positive impact on the stock returns of both small and large firms, consistent with Section 5.5. However, for medium size firms, there is no relation between these two variables.

6.3 Financial Crisis

There were two main periods of financial crisis under analysis: global Financial Crisis (2008-2010) and the COVID-19 crisis (2019-2021). These periods are characterized by uncertainty and extreme conditions, allowing me to test the resilience and validity of the findings.

Table 19. Abnormal temperatures and stock returns in crisis and non-crisis years

This Table reports the results of analyses on the effect of abnormal temperatures on stock returns over the period 2005 – 2021 and dividing my sample into non-crisis years ([2005-2007] and [2011-2018]) and crisis years ([2008-2010] and [2019-2021]). See Table 2 for definitions of Ab_Temp and Ab_Temp_Q1-Q4. Stock returns (as a percentage) is the return of stocks at month *t*. Panel B represents the result of regressing city-level abnormal temperature measures on stock returns. For each exchange city, months are sorted into quartiles based on Ab_Temp. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. I control for firm characteristics in $X_{i,t}$ including Log Total Assets, Log Leverage and Log WC/Total Assets. Serial correlation of errors and heteroskedasticity are controlled for by using robust standard errors. T-statistics are shown in parentheses. ***, ** and * represent 1%, 5%, and 10% significance levels, respectively.

	Crisis [2008-2010] and [2019-2021]		Non-crisis [2005-2007] and [2011-2018]	
	(1)	(2)	(3)	(4)
VARIABLES	Stock returns	Stock returns	Stock returns	Stock returns
Ab_Temp	0.285		-0.512***	
	(1.422)		(-4.041)	
Ab_Temp_Q1		-4.176***		0.259*
		(-5.308)		(1.923)
Ab_Temp_Q2		-3.529***		0.196
		(-4.557)		(1.512)
Ab_Temp_Q3		-4.493***		0.539***
		(-5.643)		(3.940)
Ab_Temp_Q4		-3.832***		-0.106
		(-4.948)		(-0.734)
TOTAL ASSETS	-0.000	-0.000	-0.000	-0.000
	(-1.097)	(-1.584)	(-0.287)	(-0.317)
WC ASSETS	-1.928	-2.386	-0.605	-0.610
	(-1.196)	(-1.413)	(-0.717)	(-0.737)
LEVERAGE	0.557	0.474	0.485	0.468
	(0.793)	(0.667)	(1.245)	(1.213)
Constant	-7.570***	-0.840	6.978***	1.738***
	(-3.759)	(-1.054)	(5.566)	(10.818)
Observations	15,223	15,223	27,807	27,807
Year FE	YES	YES	YES	YES
Adjusted R-squared	0.0552	0.0616	0.0165	0.0170

In Table 19, the results suggest that, in periods of crisis, the occurrence of abnormal temperatures has no impact on stock returns, and, in non-crisis periods, abnormal temperatures have a negative impact on stock returns. This may be because, in times of crisis, investors may be more focused on broader macroeconomic factors, including market volatility, government regulations and world events. In contrast, when looking at temperature quartiles, temperature has a more negative impact on stock returns during periods of crisis. However, variations within different temperature ranges show a differential impact on stock returns that may be due to sector-specific vulnerabilities or other factors associated with extreme temperatures.

Table 20. Attention to global warming and stock returns by firms' size

This Table reports the results of analyses on the effect of attention to the topic of global warming on stock returns over the period 2005 – 2021 and dividing my sample into non-crisis years ([2005-2007] and [2011-2018]) and crisis years ([2008-2010] and [2019-2021]). See Table 2 for definitions DSVI (City) and DSVI (Country). Stock returns (as a percentage) is the return of stocks at month *t* for firm *j*. The sample is from January 2005 to December 2021. Year-fixed effects and country-fixed effects are included in all regressions. I control for firm characteristics in $X_{i,t}$ including Log Total Assets, Log Leverage and Log WC/Total Assets. Serial correlation of errors and heteroskedasticity are controlled for by using robust standard errors. T-statistics are shown in parentheses. ∗∗∗, ∗∗ and ∗ represent 1%, 5%, and 10% significance levels, respectively.

	Crisis [2008-2010] and [2019-2021]		Non-crisis [2005-2007] and [2011-2018]	
	(1)	(2)	(3)	(4)
VARIABLES	Stock returns	Stock returns	Stock returns	Stock returns
DSVI (City)	-0.001		0.011***	
	(-0.082)		(4.344)	
DSVI (Country)		-0.012		0.010***
		(-1.284)		(3.194)
TOTAL ASSETS	-0.000	-0.000	-0.000	-0.000
	(-1.103)	(-1.103)	(-0.463)	(-0.474)
WC ASSETS	-1.869	-1.864	-0.594	-0.610
	(-1.161)	(-1.160)	(-0.708)	(-0.724)
LEVERAGE	0.552	0.548	0.470	0.478
	(0.788)	(0.783)	(1.213)	(1.226)
Constant	-4.732***	-4.748***	2.011***	1.999***
	(-20.061)	(-20.102)	(15.496)	(15.373)
Observations	15,223	15,223	27,807	27,807
Year FE	YES	YES	YES	YES
Adjusted R-squared	0.0551	0.0552	0.0168	0.0165

Table 20 shows that attention to the topic of global warming has a positive and statistically significant impact on stock returns during non-crisis periods, consistent with the results in Section 5.5. In contrast, during crises, the attention to the topic of global warming demonstrates a non-significant effect on stock returns.

7. Conclusion

Climate change is one of the most urgent threats the world is facing today, and preventing human-induced climate change has become a key objective of international policy. European Union is often conceived as a world leader in the fight against climate change (Claeys et al., 2019).

Previous research indicates that people can adjust to and perceive variations in the environment depending on their own observations and past experiences with the local climate. Although many different factors can influence perceptions of climate change, the focus of this article is on abnormal temperatures and natural disaster factors. Previous research has focused on elucidating the nexus between climate risks and the financial performance of portfolios. This research seeks to contribute to the ongoing discussion on climate risk within financial markets. Specifically, it aims to contribute to the understanding of how individuals adjust their perceptions of climate change and the impact this can have on stock returns.

This paper examines the effect of people's attention to climate change issues on the returns of European stocks from 2005 to 2021. To this end, I use the Google Trends' monthly Search Volume Index for the city's and country's search term ''global warming" and find no difference in investors' awareness of the risks associated with climate change especially when experiencing extreme weather or after natural disaster shocks in a particular city. In contrast, I find that investors pay less attention to global warming during both abnormally warm and cool months when examining temperature quartiles at the national level. This might occur because investors fail to consider anomalous temperatures as a potential risk and undervalue the significance of mitigating global warming because of uncertain on long-term outcomes.

How is climate change affecting stock returns? This is an important topic for policymakers looking for ways to attract investors in the fight against climate change. To answer this question, I conducted a study for both high- and low-carbon emission companies. The results show that stock returns are unrelated to investors' experience with abnormal local weather and natural disaster shocks. Interestingly, when looking at temperature quartiles, I find that abnormal temperatures have a positive effect on the returns in both high- and low-carbon emission firms. My findings suggest that there is no strong continuation or reversal of returns in the long-term.

Additional analyses of firms' carbon emissions show that there is a clear connection between abnormally high temperatures and a decrease in firms' carbon emissions as companies may perceive higher abnormal temperatures as a “wake-up” call regarding climate-related risks.

Furthermore, I conclude that during periods of crisis, the occurrence of abnormal temperatures has no impact on stock returns, which may be because investors are more focused on broader macroeconomic factors. Regarding the limitations of this work, I do not consider the sector-specific susceptibilities that may lead to variations within different temperature ranges having a different impact on stock returns. Additionally, the data sample used in this research consists of companies listed on the STOXX Europe 600 index, restricting the study to 32 European cities. Thus, it limits the generalizability of the conclusions to a wider global context because climate and market dynamics may be different in other regions.

On the other hand, this empirical study offers multiple possibilities for future research. A deeper analysis of specific sectors is recommended to understand how awareness of climate risks influences stock returns. This entails a careful investigation of sectors like tourism, energy, and agriculture to determine how vulnerable they are to high temperatures, as well as a thorough analysis of the underlying causes of such vulnerability. Identifying sector-specific vulnerabilities to temperature fluctuations is critical, and the results of this study could provide insightful information for customized policy initiatives.

In conclusion, by studying the complex connections between public awareness, climate events, and stock market dynamics, this dissertation adds to the growing research on climate change and financial markets. These results emphasize the need for a thorough understanding of how climate-related concerns interact with financial decision-making as countries and corporations struggle with the demands of sustainability. It highlights the significance of coordinating financial plans with environmentally conscientious practices to effectively address the difficulties posed by a changing global landscape.

Appendix

Table 1. Summary statistics

Variable	Obs	Mean	SD	P10	P25	P50	P75	P90
DSVI (City)	6528	-0.061	15.361	-15.000	-5.000	0.000	5.000	14.000
DSVI (Country)	6528	0.000	11.708	-12.000	-5.000	0.000	5.000	11.000
Aver_Temp	6528	10.412	2.684	6.786	9.376	10.174	11.323	14.973
Mon_Temp	6528	-0.030	6.187	-8.110	-5.323	0.062	5.287	8.361
Ab_Temp	6528	0.403	14.818	-1.764	-0.842	0.218	1.339	2.426
EMISSION EW	6528	0.750	7.908	-8.001	-3.221	0.896	4.976	9.254
CLEAN EW	6528	0.833	7.369	-7.222	-2.816	1.032	4.557	8.264
EMC EW	6528	-0.083	7.813	-8.724	-4.010	-0.098	3.900	8.569
$EMC_{t+1,t+3}$	6528	-0.083	4.598	-5.272	-2.502	-0.151	2.355	5.268
$EMC_{t+1,t+6}$	6528	-0.081	3.262	-3.953	-1.923	-0.105	1.770	3.891
$EMC_{t+1,t+12}$	6528	-0.079	2.374	-2.954	-1.424	-0.133	1.247	2.799
EMISION VW	6528	0.761	8.181	-8.289	-3.338	0.796	5.051	9.450
CLEAN VW	6528	0.857	7.626	-7.361	-2.924	1.010	4.729	8.536
EMC VW	6528	-0.097	8.459	-9.266	-4.347	-0.189	4.185	9.402
Natural_Disaster	6528	0.016	0.126	0.000	0.000	0.000	0.000	0.000

Table 8. Summary statistics

Variable	Obs	Mean	SD	P10	P25	P50	P75	P90
Stock returns	44163	0.781	9.009	-8.809	-3.830	0.823	5.358	10.061
Ab_Temp	44163	9.937	2.672	6.623	9.318	10.712	10.993	11.626
DSVI (City)	44163	-0.094	13.994	-14.000	-4.000	0.000	5.000	13.000
DSVI (Country)	44163	0.004	11.292	-12.000	-5.000	0.000	5.000	11.000
Emissions	42345	8.757	0.200	8.537	8.723	8.770	8.883	8.943

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