Is the physical risk priced by the Eurozone bond market ?

Pauline Avril

Document de Recherche du Laboratoire d'Économie d'Orléans
Working Paper Series, Economic Research Department of the University of Orléans, University Of Tours and University Clermont-Auvergne, France

DR LEO 2024-01

Is the physical risk priced by the Eurozone bond market ?

Pauline AVRIL

MISE EN LIGNE / *ONLINE* | 15 /01/2024

Laboratoire d'Économie d'Orléans
Collegium DEG
Rue de Blois - BP 26739
45067 ORLÉANS Cedex 2

TÉL | (33) (0)2 38 41 70 37
MAIL | leo@univ-orleans.fr
www.leo-univ-orleans.fr

Is the physical risk priced by the Eurozone bond market ?

Pauline Avril*

September 2023

Abstract

This paper aims to identify the presence of a physical risk exposure premium in the Euro Area bond market and to explore how previous natural disasters may influence this potential premium. Our analysis spans from 2014 to 2022 and involves a dataset of 666 bonds issued by 115 European firms. We do not find compelling evidence supporting a consistently accurate pricing of forward-looking physical risk. Nevertheless, when we look at how past events affect awareness, we see that for a company with average risk exposure, a one standard deviation increase in damages over the last three months leads to an 8.36% rise in the average spread. This spread increase remains significant when considering a six-month accumulation of prior damages but fades after one year. This suggests that investors tend to forget quickly: the majority of the risk pricing diminishes for almost all types of disasters when examining the cumulative damages over a one-year period.

JEL Classification: Q54, G12, C33

Keywords: physical risk, Euro Area bond pricing, natural disasters, re-evaluation.

* Univ. Orléans, LEO, F-45067, Orléans, France. E-mail: pauline.avril@univ-orleans.fr. The author thank XX.

1 Introduction

According to the World Meteorological Organization, in the last half-century, there has been a global rise in the occurrence of climate-related disasters, resulting in increased overall economic and financial damages. In the European Union, it has been estimated that these events have caused a staggering economic loss of 487,005 billion euros, as stated by the European Environment Agency. These past events have thus inflicted significant economic losses in Europe, but the outlook for the future is even bleaker due to the anticipated increase in both the severity and frequency of such disasters. The G20 Risk Atlas, with a specific focus on the European Union, underscores the significant influence of emission trajectories on the magnitude of damages arising from physical risks. In scenarios where temperature increases are relatively moderate, losses are projected to be approximately of €30-40 billion by the end of the century. In contrast, if emissions follow a high trajectory, the losses could soar to over €70 billion by the end of the century.

In this context, the physical risk emerges as a substantial concern not only for the overall economy but also for the financial sector. Physical risks, by causing significant business disruptions and destruction (Fankhauser and Tol, 2005), have the potential to introduce considerable challenges for companies. Furthermore, these risks can alter firms' expected profitability, potentially leading to revisions in equity prices (Carvalho et al., 2020). Additionally, the inherent uncertainty associated with various potential scenarios of accelerated climate change makes pricing climate change risks a complex task. A mispricing of these forward-looking risks could pose a significant threat to future stability and potentially lead to substantial losses for investors (Kruttli et al., 2021). Consequently, investors need to hedge against these risks.

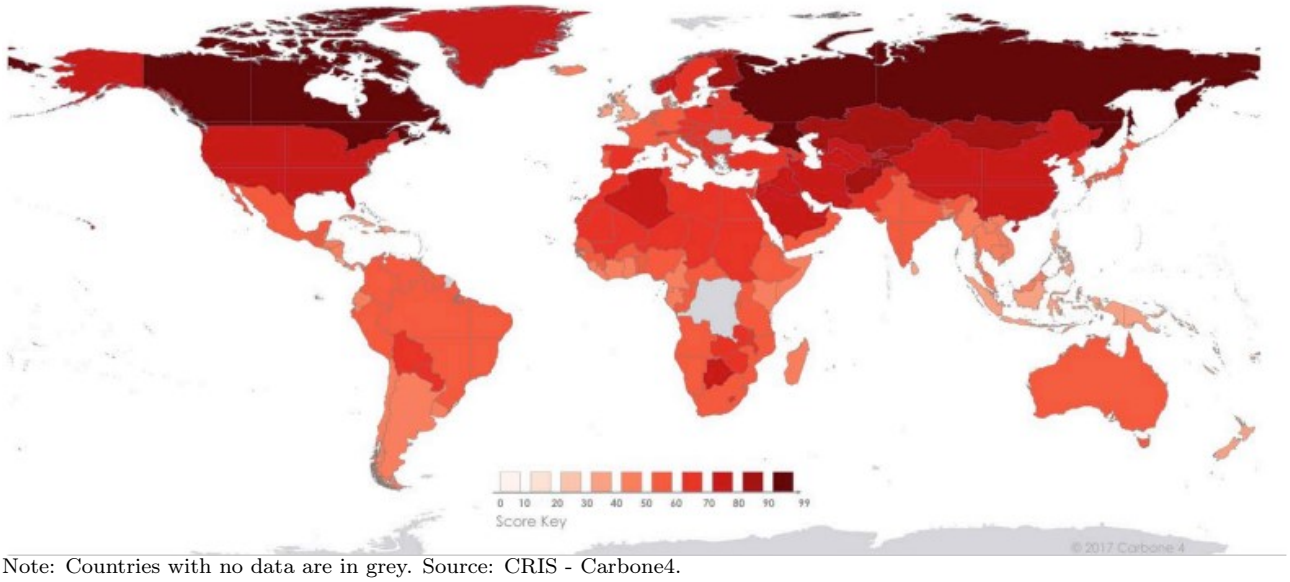
Against this background, this paper aims to delve into the assessment of forward-looking physical risk pricing within the Euro Area bond market. Furthermore, our analysis seeks to ascertain whether the occurrence of natural disasters within the region has any discernible impact on bond pricing and, if so, whether such changes in pricing persist over time.

We know that investors' decisions are rooted in their beliefs. These beliefs are, to a significant extent, shaped by past experiences. Consequently, it is quite plausible that a prior experience has led to investors becoming more aware, causing them to reevaluate a risk they had previously perceived as distant or even non-existent.

To do this, we examine the monthly bond market spread, using the European Central Bank's (ECB) yield curve as a benchmark. This yield curve is based on European triple-A-rated bonds. In our analysis, we account for all the conventional factors influencing bond spreads and incorporate a metric to gauge the forward-looking physical risk exposure of the issuing firms. The firm-level exposure to various forward-looking physical risk is quantified through a unified score system developed by Carbone4, called Climate Risk Impact Screening (CRIS). There is 7 sub-scores available representing different hazards. The overall score is a mean of those sub-scores. The computation of the exposure scores take into consideration all the various segments and operational regions of a company to provide a comprehensive assessment of its exposure. It is important to note that these scores are derived from the Intergovernmental

Panel on Climate Change (IPCC) scenarios, then the scenarios will differ in term of horizons and intensity. The exposure scores computed by CRIS will be contingent on the selected IPCC scenario. To illustrate Figure 1 depicts the geographical distribution of the score associated to increasing temperature for a long-term horizon and a high-emission scenario. In the paper, we will evaluate both the high-emissions and medium-emissions scenarios. Moreover, we opt to focus on forward-looking risk due to the medium-term maturity of bonds. It is of prime importance for investors to anticipate the future. While past experiences can provide some insights, the physical risk is on an upward trajectory and is expected to persist in this direction. To effectively hedge against these risks, medium-term investors must gain an understanding of future developments in the coming years.

Figure 1: CRIS ratings capturing increases in annual mean temperature, run for a long-term horizon and a high-emission scenario



Note: Countries with no data are in grey. Source: CRIS - Carbone4.

Our global findings indicate that, with the exception of rising heat waves, physical risk is currently not incorporated into pricing on the Euro Area market. Furthermore, by using the EM-DAT database to assess the total damages resulting from natural disasters, we find that there is an observable rise in the spread, after significant natural disaster damages. Moreover, our findings indicate that the observed outcomes are not induced by domestic disasters (occurring in countries where the firms have their headquarters), but rather by disasters within the Euro Area. This suggests that it is not solely the actual occurrence of the risk that has an impact, but rather its perception that plays a significant role. Nonetheless, our investigation reveals that this increase is short-lived, consistently dissipating within one year.

The contribution of this research stands at the crossroads of several strands of existing literature. First, we contribute to the literature on climate risk pricing within the bond market (Seltzer et al., 2022; Amiraslani et al., 2022; Safiullah et al., 2021; Stellner et al., 2015). It is worth noting that this literature predominantly focuses on evaluating transition risk. Few

contributions deal with the pricing of physical risk, and even fewer delve into its implications for the bond market. In this regard, the closest paper to ours is Ginglinger and Moreau (2019), which uses the same database on forward-looking physical risk (CRIS) on an U.S. firms sample from 2010 to 2019. While their primary focus is on the impact of physical risk on capital structure, a segment of their research focuses on the role of bond financing. Notably, they find an increase in interest rates in the bond markets for highly-exposed firms following the Paris Agreement. Given that there is limited existing research on the subject, our study first contribution is to offer new insights into the pricing of physical risk, a dimension that holds longer-term significance for investors.

A majority of research in this field has primarily focused on the U.S. market. Nevertheless, it is crucial to highlight the role played by the European bond market as well. Indeed, at the end of 2021, the Euro area represented around 12% of the world non-financial corporations bond market.[1] Our second contribution is to initiate this study on the Eurozone corporate bond market. As pointed out by Darmouni and Papoutsi (2022), the Eurozone initially leaned toward a bank-centered system, but since 2000, the bond market has outpaced the banking sector's growth. This shift is attributed to reduced access to bank loans after the Global Financial Crisis and stricter regulations. The authors also note a surge in smaller, higher-risk issuers in recent years. Given this transformation, it's crucial to study the evolving Euro Area bond market. Our third and final contribution pertains to the body of literature that examines the revision of beliefs. As exemplified in studies such as Letta et al. (2022), market prices adapt to the non-linear effects of unusual weather. In this paper, our objective is to offer new evidence regarding how past events play a role in shaping awareness and, consequently, how they influence risk premiums (Chen et al., 2012). We demonstrate that after natural disasters occur, there is a rise in the risk premium, thus supporting the theory of belief revision.

The remainder of this paper is structured as follows: In Section 2, we provide an overview of the literature and outline our hypotheses. Section 3 is dedicated to presenting our data and offering some descriptive statistics. Section 4 delves into our examination of the influence of forward-looking physical risk on the Euro Area bond market. In Section 5, we explore the market's response following natural disasters. Our robustness analysis is presented in Section 6. Subsequently, in Section 5.2, we scrutinize the proximity of the risk. Finally, Section 7 provides our concluding remarks.

2 Literature review and hypothesis development

The majority of studies examining how climate risk is assessed in the bond market primarily concentrate on transition risk. This can be explained by the anticipated costs associated with the transition to a more environmentally sustainable economy, including regulatory risk stemming from changes in regulations and reputational risk arising from shifts in investor perceptions and beliefs. Seltzer et al. (2022) find a link between poor environmental performance of companies

[1] See Tresor-Economics note No. 313 of September 2022

and the amplification of yield spreads alongside a reduction in credit ratings, particularly for companies functioning in areas with strict environmental regulation. In the same vain, Amiraslani et al. (2022) find that during the 2008 financial crisis, the secondary market bond spreads of high Environmental and Social (E&S) firms did not rise as much as the spread of low E&S firms. Moreover, Safiullah et al. (2021) found that emissions have a significant negative effect on credit ratings and that the effect of direct emissions is more pronounced. Nonetheless, it's important to emphasize that these studies specifically deal with on the U.S. market. In contrast, Stellner et al. (2015) find no consistent evidence that high Corporate Social Performance (CSP) reduces credit risks in the Euro Area.

On the contrary, there is a limited body of literature that delves into the pricing of physical risks (i.e. natural disasters) in the bond market. This can be explained by the fact that these climate risk seems less of a concern for investors. The issue of climate change is examined in a comprehensive survey conducted by Stroebel and Wurgler (2021) involving various actors of the financial domain. The findings indicate that respondents commonly regard regulatory risks as the more immediate climate concern, whereas physical climate risks are viewed as longer-term risks, extending over the next three decades.

However, a part of the literature has demonstrated that physical risk poses a significant threat to companies' profitability, financing, and investment. Thus, Kling et al. (2021) identified that companies with greater exposure to climate risks experience elevated financing expenses and encounter more pronounced financial limitations. Similarly, Huynh et al. (2020) reveal that droughts lead to higher funding costs for businesses. The study carried out by Hosono et al. (2016) reveal a decline in the capital investment ratio of firms subsequent to the Hanshin-Awaji earthquake. Additionally, Basker and Miranda (2018) found a decrease in the survival rate of smaller and less productive companies following the aftermath of Hurricane Katrina.

These studies provide insights into the adverse impact of natural disasters on firms' operations, subsequently elevating the risks they encounter. However, the evidence regarding the pricing of these risks are mixed. For instance, Correa et al. (2020) demonstrate that borrowers indirectly affected by natural disasters tend to experience higher spreads on their loans subsequent to such events. This effect becomes more pronounced during periods of heightened media attention on climate change and in the case of the most severe disasters. Similarly, Huynh and Xia (2021) shows that firms investing in improving their environmental performance face lower costs for their debt financing and better respond when physical risk materialized. In contrast, Manela and Moreira (2017) conclude that natural disasters do not serve as robust predictors for market returns. Furthermore, Hong et al. (2019) find inefficiencies in stock markets related to the pricing of information concerning drought trends, particularly within the food industry sector.

Few studies have examined the valuation of natural disaster risks on the bond market. Furthermore, those that have tend to focus on the municipal bond market. Painter (2020) emphasize the importance of beliefs about the forward-looking climate risk in the U.S. municipalities bond market. Investors factor take into account uncertainty when evaluating municipal bonds issued in counties with elevated climate change risk, irrespective of whether those counties

will ultimately experience the effects of climate change. This conclusion, however, is particularly relevant to long-term municipal bonds. Additionally, Goldsmith-Pinkham et al. (2022) identify a substantial impact of sea level rise risk on default risk for municipal bonds, with this effect being found across both short and long-term maturities, albeit more pronounced in the long term.

Regarding physical risk, it is important to note that channels at stake are not reputational nor regulatory. Regarding physical risks, the primary mechanism at play involves the risk of deteriorating the balance sheet and devaluing assets. Indeed, bonds' pricing should react to the potential threat of natural disasters shocks, which can introduce uncertainty for companies in terms of profitability, funding expenses, credit reimbursement and operational costs. With regard to the literature, the first research question we investigate is the following: are firms exposed to high forward-looking risk of natural disasters bear higher risk premia in their bonds ? In this line, we exclusively focus on the forward-looking risk of natural disasters, based on medium-term scenarios. Nevertheless, past encounters with similar risks can shape behaviors in relation to this particular risk. Bourdeau-Brien and Kryzanowski (2020) demonstrate through their empirical findings that natural disasters induce a notable and meaningful rise in risk aversion at the local level. This effect can potentially enhance the perceived importance of risk management initiatives and infrastructural investments. Furthermore, the theoretical framework of Chen et al. (2012) demonstrates that the premium for physical risk is expected to be minimal during normal periods. Nonetheless, after a catastrophic event, this risk premium will experience a significant surge. This is due to the fact that the natural disasters' impact on consumption and wealth alters the outlook of optimistic investors, leading them to align their beliefs regarding disasters with those of pessimistic counterparts. The findings of Kruttli et al. (2021) are consistent with the aforementioned model. Specifically, their research identifies instances of under-reaction in stock returns to the volatility generated by hurricanes. Although hurricanes did not lead to increased expected returns for affected companies across the entire dataset, following Hurricane Sandy, hit firms did experience positive expected returns in the wake of this event. Subsequently, it becomes clear that the perception of risk is influenced to a certain extent by the experience of it. Indeed, significant past events can mold perceptions of potential future risks. These insights provide the foundation raising a follow-up research question. The occurrence of a natural disaster should update the beliefs, making the risk associated more imminent. Hence, we investigate whether in the wake of natural disasters events there is a rise in the risk premia for Euro Area bonds.

3 Data

3.1 Construction of the sample, measure of risk and control variables

We focus in our study on the Eurozone. First, we employ Thomson Reuters Eikon to identify non-financial companies situated within the Euro Area that have issued bonds denominated in euros. While a majority of studies concentrate on the US bond market, we opt to delve into the

Euro Area market in order to bring novel insights into the valuation of climate risk. Subsequently, we proceed with the task of integrating these companies into the Climate Risk Impact Screening (CRIS) database provided by Carbon4. This database provides details regarding the potential physical risks attributed to forthcoming climate changes for companies. Employing the ISIN code, we establish a correspondence with the CRIS database, resulting in a dataset of 223 companies that have issued a total of 1,564 bonds.

Our dependent variable is computed as the monthly yield spread at the level of individual bonds, enabling us to gauge the associated risk with each bond. The spread is determined in the following manner: on a monthly basis, we take the mid yield of a bond i from Thomson Reuters Eikon and subtract the yield corresponding to the same remaining maturity from the yield curve constructed by the European Central Bank (ECB). This yield curve is established using a Svensson model and encompasses all issuers with a triple-A rating, which is regarded as risk-free. The ECB's yield curve starts at a maturity of 10 months and extends up to 30 years.[2] Additionally, we apply a 1% winsorization to the spread to prevent our outcomes from being influenced by outliers. Subsequently, we retain only those bonds for which we possess yield-related information, resulting in a subset of 1,000 bonds originating from 190 distinct firms.

Next, we narrow our focus to exclusively include bonds that hold ratings from one of the prominent rating agencies (S&P, Fitch, Moody's). Lastly, we eliminate certain bond types, namely convertible, exchangeable, putable, floating, zero-coupon, perpetual, preferred, structured, and asset-backed securities as it is common in the literature. Ultimately, after applying filters and accounting for the availability of control variables, our dataset comprises an unbalanced panel of 666 bonds stemming from 115 Euro Area companies, spanning the time frame from 2014 to 2022 and covering 8 countries.

Concerning the control variables, we follow the literature (Stellner et al., 2015; Seltzer et al., 2022; Amiraslani et al., 2022) by incorporating both bond-level and firm-level characteristics (see Section B for details on the variables construction).

At the bond level, we incorporate variables such as the logarithm of the issued amount, time to maturity, callable indicator, coupon rate, Roll illiquidity, and credit ratings. These control variables come from Thomson Reuters Eikon. Ratings are transformed into numerical values, with 1 corresponding to the lowest grade (D) for S&P and Fitch, and (C) for Moody's, while 22 corresponds to the highest grade (AAA) for S&P and Fitch, and (Aaa) for Moody's.[3] In cases where a bond receives ratings from multiple agencies, we retain the highest grade, representing the best rating. Concerning the monthly absolute Roll measure of illiquidity ($\hat{\lambda}$) the objective if to reproduce a theoretical bid-ask spread based on daily close price (see Section B for the complete formula).

At the firm level, we incorporate the logarithm of total assets, leverage, debt service capability, cash to assets, operating profit margin, tangibility, annual returns and the CAPEX ratio. We also

[2]For bonds that maturities are lower than 10 months, we employ the 10-months ECB yield as the reference yield, while for maturities exceeding 30 years, the 30-year yield is used.

[3]See Table A1 for details.

add the monthly volatility of returns calculated on a rolling window of one year. Additionally, a carbon premia can arise when looking at the risk associated to a bond (Safiullah et al., 2021). Hence, we control for the carbon risk by adding as control the carbon intensity of firm.

Finally, as we work on a sample of multiple Euro Area countries, we opt to account for the coping capacity in term of natural disasters in the country where the firm's headquarters are situated. This consideration is prompted by the understanding that these factors could significantly influence bond pricing in terms of how the anticipated effects are perceived.

3.2 Climate Risk Impact Screening (CRIS)

CRIS (Carbon Risk Integration System), is a database created by Carbon4.[4] This database computes indicators related to potential physical risks arising from anticipated climate changes. With regard to evaluating climate risk at the firm level, the calculations rely on climate projections tailored to particular geographical areas and vulnerabilities specific to various sectors. Each climate risk rating is determined by combining location-specific climate hazards with sector-specific vulnerabilities.

The indicators are derived from the scenarios presented in Assessment Report 5 of the Intergovernmental Panel on Climate Change (IPCC), encompassing three scenarios of emission levels (low, medium, and high) and for two horizons (2050 and 2100). Given that we analyse bonds with a moderately near-term maturity (average year to maturity of about 8 years), we concentrate on the 2050 horizon and specifically focus on the high-emission scenario.[5] However, as mentioned in the work of Ginglinger and Moreau (2019), it is important to bear in mind that climate risk will progressively manifest in the years ahead.

The ratings are computed using a bottom-up approach, encompassing a numerical range from 0 to 99. For instance, in the case of a company engaged in diverse sectoral activities across various countries, the assessment is initially carried out for each sector within each country, before being aggregated at the company-wide level.[6] The identification of a firm's activities is established through its financial statements. In the situation, where a firm operates across multiple business segments (encompassing various sectors and countries), the risk rating for each hazard is determined by calculating the weighted mean of all the risk ratings computed for each of the firm's business segments for that particular hazard. The weights are determined by the proportional contribution of the firm's revenue or fixed assets (in case of capital-intensive segments) within each segment. For each hazard, the risk rating attributed to a specific sector within a specific country is a composite of the country's hazard rating and the sector's vulnerability rating. To illustrate the computation of the score see Appendix A, where we provide CRIS example for a fictional firm.

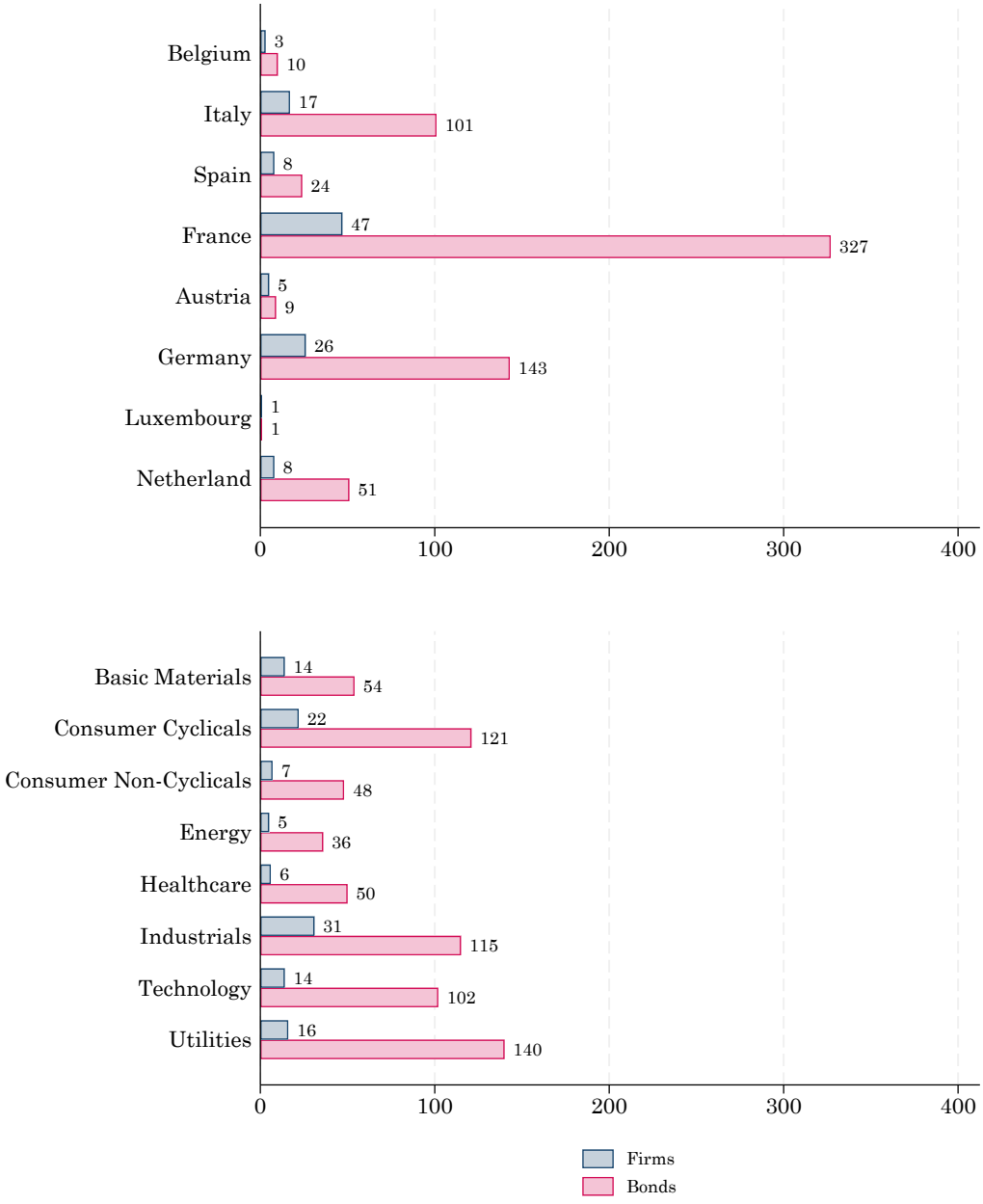
The database provides seven distinct sub-scores tailored to various types of climate hazards: increase in average temperature, increase in heatwaves, amplification of droughts, alterations in

[4]You will find more details on the Carbon4 organism and the database here.
[5]You will find the results using the medium-emission scenario in Section 6.2.
[6]CRIS considers data from 210 countries and 60 sectors.

rainfall patterns, augmentation in heavy rainfall, rise in sea levels, and intensification of storms. Additionally, an aggregate score is available, which is computed as the weighted geometric mean derived from all the risk ratings calculated for each of the seven aforementioned hazards.

3.3 Descriptive statistics

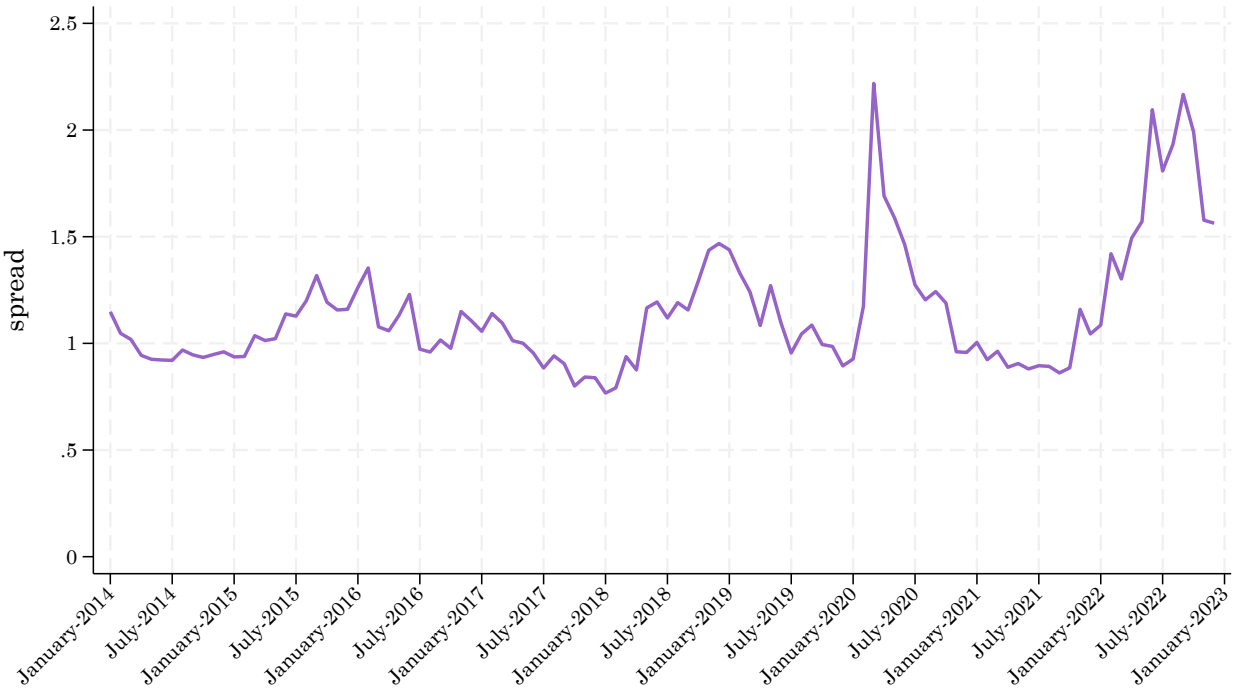
Figure 2: Geographic and sectoral composition of the sample



Note: The bars represent the number of firms (blue) or bonds (bond).

Our analysis is based on the Euro Area. As shown by Figure 2 we have collected bonds from 8 countries due to the availability of the data. Nonetheless, to analyse changes in awareness we use as natural disasters all the event happening in the 20 countries that are part of the Eurozone.

Figure 3: Average spread evolution



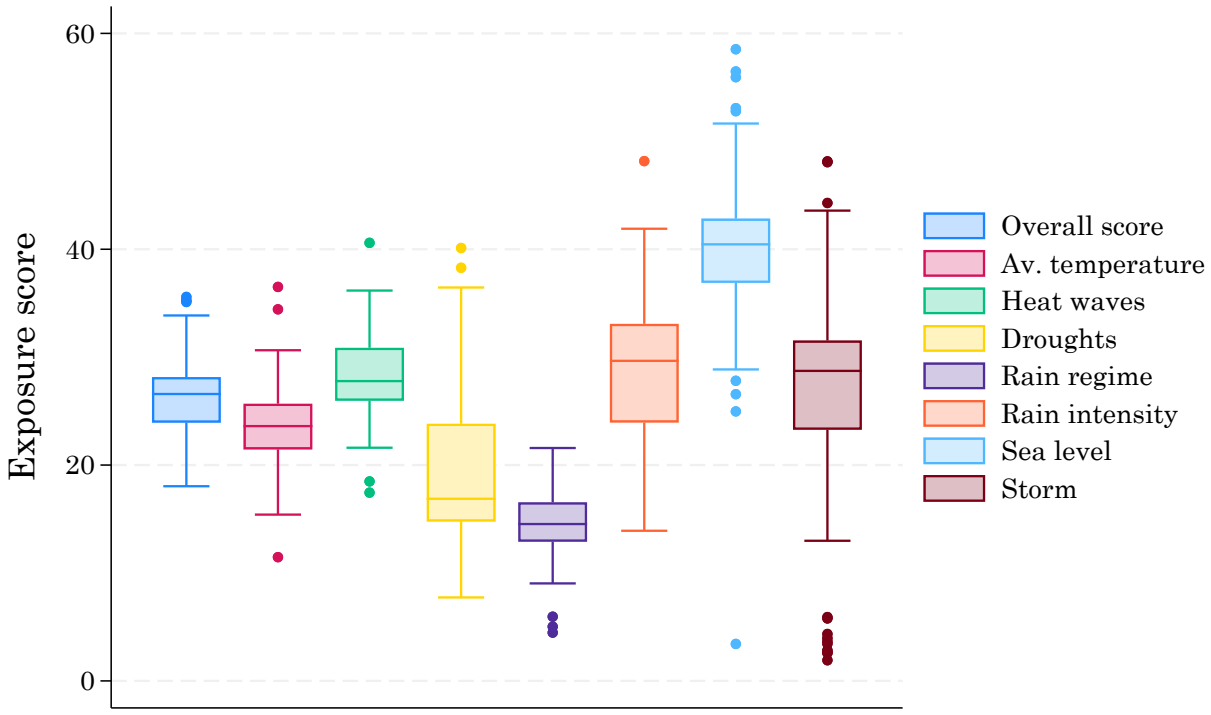
Note: The line represent the average spread in our sample, by month.

However, as shown by Figure 2 we have collected bonds from 8 countries due to the availability of the data. Our sample contains a greater number of firms from France and Germany, which are responsible for issuing the majority of bonds in our dataset, approximately 70.5%. This is due to the fact that France and Germany represent a large share of the European corporate bond market (European Commission, 2017). When examining the sectoral distribution, our sample is more evenly distributed. Despite the prevalence of certain sectors, both in terms of firms and bonds—namely Utilities, Consumer Cyclicals, Industrials, and Technology—the overall sectoral distribution seems to be more balanced.

The summary statistics for all our variables can be found in Table A2. However, our current focus will be directed towards a more detailed examination of both our dependent variable and the variable of interest.

Examining Figure 3, it appears that the average spread across our sample seems to center around 100 basis points (1%), except towards the end of our observed period. Indeed, the substantial spike in spread at the outset of 2020 corresponds to the period of the Covid-19 pandemic, and this spike is mitigated following the introduction of the Pandemic Emergency Purchase Programme (PEPP) jointly with Government-guaranteed loan (GPL) and the use of macroprudential instruments. Additionally, the notable increase starting in 2022 coincides with the European Central Bank's decision to raise interest rates. One of the advantages of working at the Euro Area level is the homogeneity of risks. This mitigates our concerns about a different exposition to other shocks.

Figure 4: Distribution of exposure scores



Note: In this box plot, the points represent the outliers. Starting from the top, the first line is the upper adjacent value, the second is the upper quartile, the third is the median, the fourth is the lower quartile and the fifth the lower adjacent value.

Finally, Figure 4 depict the distribution of natural disasters exposure scores across natural disasters hazards. Within the CRIS database, it is possible to access information on various types of exposures, encompassing both *acute risks* (heat waves, droughts, and storms) as well as *chronic risks* (average temperature, rainfall regime, rain intensity, and sea level). We discern that within this plot the most elevated risk within our dataset is associated with sea level exposure. Moreover, among the categories considered, the distributions for drought, rain intensity, and storms exhibit the highest levels of dispersion. However, when we narrow our focus to the high-risk segment (top quartile), it becomes apparent that the most significant risks are linked to heat waves, rain intensity, and storms. On the other hand, it seems that concerns related to rain patterns and droughts are less prominent within our sample. The distribution of the overall score appears relatively concentrated, with an upper quartile score of around 28.5, a median score of 26.7, and a lower quartile of 24.

This analysis highlights that exposure heterogeneity is more pronounced when examining sub-scores as opposed to the overall score.

4 The pricing of forward-looking natural disaster risk on the Euro area bond market

The first step of our analyse in to investigate how forward-looking risks of natural disasters are priced on the Euro area bond market. They can be priced or not, according to the importance given by the investors.

Our identification strategy for this first hypothesis is based on a panel model that allow us to control for all the traditional determinants of bonds spread. Our focus is on the interpretation and the significance of the relation between the forward-looking exposure of the firm and its bonds spread. Then, we estimate the following model using monthly spread data:

$$Y_{i,t} = \beta_1 ExposureScore_j + \beta_2 W_{i,t} + \beta_3 X_{j,t-1} + \beta_4 Z_{c,t-1} + FE + \varepsilon_{i,t}, \quad (1)$$

where $Y_{i,t}$ is our dependent variable, the monthly spread for a corporate bond i at time t. $ExposureScore_j$ is our variable of interest, the forward looking exposure score to natural disasters for a company j that have emitted the bond. [7] We will consider 8 exposure scores. $W_{i,t}$ represent a set of bond-specific characteristics that can influence the spread behavior. [8] As bond-level characteristics we use: logarithm of the amount issued, year to maturity, callable status of the bond, coupon rate, credit rating and absolute Roll measure of illiquidity. $X_{j,t-1}$ represent a set of firm-specific characteristics at $t-1$. We include at a firm level: logarithm of total assets, leverage, debt service capability, cash to assets, operating profit margin, tangibility, annual returns, volatility of returns, CAPEX ratio and the carbon intensity. [9] Finally, $Z_{c,t-1}$ represents a country specific time-varying characteristic in t-1, the lack of coping capacity.

All our specifications include both time and industry fixed effects (columns (1), (3), (5) and (7)), and in some of them we add country fixed effects (colums (2), (4), (6) and (8)). Our standard error are clustered at the firm level to control for cross-sectional dependence.

Our results are presented in Table 1 and Table 2.

Our interest lies in the relation between the exposure and the bond spread. We estimate 8 models with different exposure measures. First, we consider the overall score. Then, we investigate individually the 7 sub-score constituting the main score. Column (1) and (2) in Table 1 do not provide any indication of a significant pricing related to the overall risk of future natural disasters. Ginglinger and Moreau (2019) found a significant effect of the overall risk after the Paris Agreement on the cost of bonds, only for high risk firms. However, even when transforming the exposure score into a more restrictive definition for high-risk and low-risk firms we find no significant pricing of the overall risk (column (1) in Table A3). This could be due to the fact that we work in a more narrow geographic area (i.e. the Euro area). With the Paris

[7] Note that we use in the main table this measure as a continuous variable, but we will explore the potential nonlinearities by converting it into a dummy that will take the value of 1 for the top-quartile (i.e. the most exposed firms).

[8] Note that the controls variables can be time-varying or not

[9] Following the literature, we winsorized the spread and the following controls : illiquidity, logarithm of total asserts, leverage, debt service capability, operating profit margin, tangibility, annual returns, volatility of returns, CAPEX ratio and carbon intensity.

Table 1: Natural disasters exposure and bond spreads - 1/2

	Overall score		Av.temperature		Heat waves		Droughts	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposure score	-0.012	-0.000	0.020	0.009	0.038***	0.026*	0.016**	0.010
	(0.014)	(0.013)	(0.016)	(0.016)	(0.014)	(0.014)	(0.007)	(0.007)
Log of amount issue	-0.016	-0.029	-0.021	-0.030	-0.016	-0.026	-0.010	-0.024
	(0.028)	(0.026)	(0.027)	(0.025)	(0.026)	(0.024)	(0.027)	(0.025)
Year to maturity	0.021***	0.021***	0.021***	0.021***	0.021***	0.021***	0.021***	0.021***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Callable	0.130**	0.219***	0.129**	0.215***	0.133**	0.205***	0.133**	0.219***
	(0.065)	(0.057)	(0.064)	(0.057)	(0.063)	(0.054)	(0.067)	(0.057)
Coupon rate	0.076***	0.080***	0.075***	0.079***	0.072***	0.077***	0.072***	0.079***
	(0.023)	(0.024)	(0.024)	(0.025)	(0.024)	(0.024)	(0.023)	(0.024)
Ratings	-0.216***	-0.206***	-0.220***	-0.209***	-0.224***	-0.217***	-0.226***	-0.212***
	(0.028)	(0.028)	(0.028)	(0.028)	(0.029)	(0.029)	(0.029)	(0.029)
Illiquidity measure	0.507***	0.492***	0.505***	0.491***	0.498***	0.487***	0.499***	0.488***
	(0.090)	(0.086)	(0.090)	(0.086)	(0.088)	(0.084)	(0.089)	(0.086)
Logarithm total assets	0.014	0.067*	0.015	0.068*	0.014	0.064*	0.029	0.074*
	(0.040)	(0.039)	(0.042)	(0.038)	(0.042)	(0.038)	(0.043)	(0.039)
Leverage	0.062**	0.070**	0.073***	0.075**	0.081***	0.080**	0.073**	0.072**
	(0.029)	(0.029)	(0.028)	(0.030)	(0.029)	(0.031)	(0.029)	(0.030)
Debt service capability	0.005	0.003	0.003	0.003	0.004	0.003	0.005*	0.004
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Cash to assets	-0.003	-0.002	-0.003	-0.002	-0.004*	-0.002	-0.004*	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Operating profit margin	-0.004	-0.005	-0.005	-0.006	-0.005	-0.005	-0.005	-0.005
	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)
Tangibility	0.048	-0.036	0.073	-0.025	0.014	-0.083	-0.016	-0.083
	(0.267)	(0.283)	(0.253)	(0.283)	(0.242)	(0.274)	(0.251)	(0.268)
Annual returns	-0.981***	-1.016***	-0.918**	-1.004***	-0.901**	-0.982***	-0.883**	-0.979***
	(0.371)	(0.366)	(0.377)	(0.367)	(0.360)	(0.359)	(0.368)	(0.363)
Volatility of returns	2.875***	2.702***	2.682***	2.652***	2.618***	2.577***	2.721***	2.648***
	(0.591)	(0.569)	(0.571)	(0.560)	(0.586)	(0.580)	(0.561)	(0.561)
CAPEX ratio	0.007	0.006	0.009*	0.007	0.004	0.005	0.005	0.005
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Carbon intensity	0.540	0.656	0.117	0.525	0.645	0.741	0.229	0.580
	(0.997)	(0.790)	(0.920)	(0.755)	(0.746)	(0.737)	(0.914)	(0.776)
Lack of coping capacity	0.400***	-0.254	0.389***	-0.251	0.204	-0.235	0.267**	-0.249
	(0.124)	(0.211)	(0.127)	(0.212)	(0.135)	(0.209)	(0.126)	(0.210)
Time FE	✓	✓	✓	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓	✓	✓	✓
Country FE		✓		✓		✓		✓
N	30998	30998	30998	30998	30998	30998	30998	30998
Number firms	115	115	115	115	115	115	115	115
Number bonds	666	666	666	666	666	666	666	666
R^2	0.697	0.713	0.699	0.713	0.704	0.715	0.700	0.714

Significance levels are: * p < 0.10 ; ** p < 0.05 ; *** p < 0.01

Table 2: Natural disasters exposure and bond spreads - 2/2

	Rain Regime		Rain Intensity		Sea level		Storm	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposure score	-0.025	-0.022	-0.014**	-0.011	-0.009	-0.006	-0.009*	0.000
	(0.020)	(0.021)	(0.007)	(0.008)	(0.005)	(0.006)	(0.005)	(0.006)
Log of amount issue	-0.021	-0.032	-0.016	-0.027	-0.012	-0.026	-0.013	-0.030
	(0.028)	(0.027)	(0.027)	(0.025)	(0.029)	(0.027)	(0.027)	(0.026)
Year to maturity	0.021***	0.021***	0.021***	0.021***	0.021***	0.021***	0.021***	0.022***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Callable	0.125*	0.220***	0.127*	0.216***	0.137**	0.223***	0.147**	0.219***
	(0.064)	(0.056)	(0.064)	(0.056)	(0.067)	(0.057)	(0.063)	(0.057)
Coupon rate	0.074***	0.082***	0.072***	0.079***	0.078***	0.082***	0.078***	0.080***
	(0.023)	(0.024)	(0.023)	(0.024)	(0.024)	(0.025)	(0.024)	(0.024)
Ratings	-0.226***	-0.207***	-0.214***	-0.203***	-0.218***	-0.204***	-0.208***	-0.206***
	(0.026)	(0.026)	(0.027)	(0.027)	(0.027)	(0.027)	(0.028)	(0.027)
Illiquidity measure	0.508***	0.495***	0.509***	0.494***	0.503***	0.491***	0.502***	0.492***
	(0.090)	(0.086)	(0.089)	(0.086)	(0.089)	(0.086)	(0.090)	(0.086)
Logarithm total assets	0.030	0.071*	0.011	0.060	0.011	0.060	0.024	0.067*
	(0.040)	(0.036)	(0.038)	(0.036)	(0.041)	(0.040)	(0.040)	(0.038)
Leverage	0.055**	0.059**	0.059**	0.064**	0.069**	0.071**	0.063**	0.070**
	(0.027)	(0.029)	(0.027)	(0.029)	(0.029)	(0.030)	(0.028)	(0.030)
Debt service capability	0.005*	0.004	0.005*	0.004	0.005	0.003	0.004	0.003
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Cash to assets	-0.003	-0.002	-0.003*	-0.002	-0.003	-0.002	-0.003	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Operating profit margin	-0.004	-0.005	-0.005	-0.005	-0.003	-0.005	-0.005	-0.005
	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)
Tangibility	-0.025	-0.085	0.005	-0.079	0.077	-0.010	-0.013	-0.035
	(0.257)	(0.267)	(0.264)	(0.276)	(0.263)	(0.281)	(0.272)	(0.285)
Annual returns	-0.988***	-1.058***	-1.038***	-1.095***	-0.969**	-1.033***	-0.990***	-1.014***
	(0.367)	(0.358)	(0.359)	(0.349)	(0.371)	(0.363)	(0.372)	(0.364)
Volatility of returns	2.752***	2.681***	2.947***	2.810***	2.840***	2.755***	2.921***	2.696***
	(0.531)	(0.530)	(0.554)	(0.525)	(0.558)	(0.554)	(0.591)	(0.555)
CAPEX ratio	0.007	0.006	0.006	0.005	0.006	0.005	0.006	0.007
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Carbon intensity	0.599	1.036	0.907	1.087	0.334	0.749	1.058	0.634
	(1.013)	(0.755)	(0.896)	(0.764)	(1.002)	(0.768)	(0.919)	(0.816)
Lack of coping capacity	0.434***	-0.244	0.369***	-0.266	0.396***	-0.255	0.283**	-0.254
	(0.123)	(0.214)	(0.120)	(0.209)	(0.122)	(0.208)	(0.120)	(0.210)
Time FE	✓	✓	✓	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓	✓	✓	✓
Country FE		✓		✓		✓		✓
N	30998	30998	30998	30998	30998	30998	30998	30998
Number firms	115	115	115	115	115	115	115	115
Number bonds	666	666	666	666	666	666	666	666
R^2	0.700	0.715	0.700	0.714	0.699	0.713	0.700	0.713

Significance levels are: * p < 0.10 ; ** p < 0.05 ; *** p < 0.01

Agreement, there is an universal acknowledgment of environmental concerns. To be sure that the pricing is not appearing only after this significant event, we re-estimate our model starting in November 2016, as detailed in Section 6.1.

However, intriguing patterns emerge while examining the dis-aggregated indicators. Only a subset of the forward-looking disaster risks are accurately priced into the bond costs. Indeed, we notice that only the risks of heat waves and droughts (columns (5) to (7) in Table 1) have a significant and positive impact on the rise of the spread. However, the impact of drought risk disappear when taking into account country fixed effect that are essential to encompass geographical features (column (8) in Table 1). Interestingly, the risks associated with rain intensity and storms (columns (3) and (7) in Table 2) are priced significantly in the opposite sign, yet these effects also vanish when country fixed effects are introduced (columns (4) and (8) in Table 2). In this particular specification, the sole effect that stands out as robust is the heat waves exposure. To provide a more insightful interpretation, our findings indicate that an elevation of one standard deviation in heat wave exposure (3.53) leads to a 92 basis points rise in the spread. Considering that the mean spread within our sample is 1.22, this effect corresponds to a 75% increase relative to the average spread.

In order to examine the possibility of non-linearities in the relation between the spread and exposure scores, we convert the exposure scores into dummy variables. These dummies will be equal to 1 when the firms fall within the top quartile of the distribution for each score. Results are presented in Table A3, we found that the results concerning the pricing of the heat waves risks are robust using the dummy. However, the positive pricing of droughts as well as the negative pricing of the rain intensity and storm exposure in the absence of country fixed-effect disappear. Moreover, we found a pricing of the average temperature only in the absence of country fixed-effect.

We notice that the control variables that are significant in our model have the expected signs, which can also explain the high R^2 we obtain. An increase in the time to maturity leads to higher spread, called the term risk. The risk increase with the duration due to the fact that more events might compromise the interest and principal payments (King and Khang, 2005). The callable feature of the bond is also important to take into account (Duffee, 1998). The positive and significant nature of being callable can be attributed to its heightened sensitivity to uncertainties concerning changes in interest rates. The effect of coupon rate is explained by tax-related effect (Krylova, 2016). The rationale behind the increased premium for a higher coupon rate lies in the fact that a lower coupon rate can lead to savings in tax expenses. The relationship between credit ratings and their impact remains highly consistent. The ratings assigned by agencies are meant to evaluate the level of risk associated with the issuer. Therefore, it is logical to infer that a higher rating (indicating a lower risk) would lead to a decrease in the premium. Concerning the measure of illiquidity, as shown in several paper, higher liquidity results in a lower spread (Acharya and Pedersen, 2005; De Jong and Driessen, 2012; Lin et al., 2011). On the contrary, higher illiquidity results in an higher spread. More leveraged firms have higher chances of default which can explain their higher spreads (Merton, 1974). We also find

that higher annual returns lead to lower spreads. Returns can translate the healthiness of a company and also take into account cycles in the firm's environment. However, higher volatility of returns generate an increase of the premia as a result of higher uncertainty (Campbell and Taksler, 2003). We do not uncover any indications supporting the presence of a carbon premium within our dataset. It is important to note that there is currently no unanimous consensus in the academic literature regarding the existence of a carbon premium. Certain studies have identified a notable influence on returns (Bolton and Kacperczyk, 2021), while others have found no substantial effects (Görgen et al., 2020). Lastly, with regard to the ability to handle natural disasters at the country level, we observe that this variable exhibits the expected effect when country fixed-effects are not considered. Specifically, when the issuing firm operates in a country with a greater deficiency in coping capacity, the risk associated with the bond tends to rise. However, this relationship becomes insignificant upon introducing country-specific effects, indicating that this aspect is likely to be incorporated within those fixed effects due to its limited temporal fluctuation.

Overall, our findings suggest limited pricing of forward-looking exposure risks over the analyzed period. Consequently, it becomes clear that the consideration of physical risk is not a priority as it is not adequately priced within the Euro area bond market, except in the case of heat waves exposure. This observation gives rise to our follow-up investigation: investors may only factor in this risk if they perceive it to be imminent. As a result, it is plausible to postulate that significant events involving natural disasters could influence the pricing of companies with high future exposure to these events.

5 The impact of natural disasters experience

In this section, our goal is to assess whether the occurrence of natural disasters in the Eurozone triggers a shift in investor beliefs and elevates their awareness of forthcoming physical risks. We then delve into whether this increase in awareness is a result of domestic disasters or extends more broadly across the Euro Area.

5.1 Changes in physical risk awareness

As stated previously, our follow-up hypothesis concern the update of beliefs that might affect the discount rate and create revisions in the pricing of bonds. As shown by Chen et al. (2012), disasters risk premium should be low during normal times. However, following a disaster event, the risk premium will increase substantially because the disaster affects the consumption and wealth of these optimistic investors, causing their beliefs about disasters to converge toward those of pessimists. Moreover, Malmendier and Nagel (2011) argued that macroeconomic shocks can have long-term repercussions on beliefs. Hence, we can wonder if it would be the case for natural disaster events. To test this, we add an interactive term to our previous model that is computed as the sum of previous damages caused by natural disasters in the Euro area. We use different time-window for computing prior damages to see if the repricing effects hold in the

long run.

We can argue that damages are usually prone to an endogenity issue (Felbermayr and Groschl, 2014). Nevertheless, in this particular instance, concerns can be eased. First, the issue stems from disparities in reporting, which might vary significantly among countries with different level of income. Given our focus on the Euro area, the potential differences become less worrisome. Second, we work on the reaction of investors: the objective here is not to have a proxy of the physical intensity of the disasters but rather a measure of visibility for investors. We want to measure how investor perceive the event.

Subsequently, in order to assess the impact of past disasters on bonds pricing within the Euro area, we calculate the accumulated damages over the preceding time frames (3 months, 6 months, 1 year), rescaled by the Eurozone GDP. We consider multiple time horizons, recognizing that investor reactions may not be sustained over extended periods. This is especially relevant if investors exhibit short-sighted tendencies, as their re-pricing behavior might not persist even following an important event. We estimate the following model:

$$\begin{aligned} Y_{i,t} = \beta_1 ExposureScore_j + \beta_2 ExposureScore_j \times \sum_{h=0}^{m} DamagesEA_t \\ + \beta_3 W_{i,t} + \beta_4 X_{j,t-1} + \beta_5 Z_{c,t-1} + FE + \varepsilon_{i,t} \end{aligned} \tag{2}$$

where $Y_{i,t}$ is our dependent variable, the monthly spread for a corporate bond i at time t. $ExposureScore_j$ is the forward looking exposure score to natural disasters for a company j that has emitted the bond. We will consider the score as a continuous variable as well as a dummy variable as previously in two sets of regressions to take into account potential non linearities. The bond-specific characteristics ($W_{i,t}$), the firm-specific characteristics ($X_{j,t-1}$) and the country-specific characteristic ($Z_{c,t-1}$) are the same as in the previous model. Here again, standard errors are clustered at the firm level. Our interest variable here is the interaction between the exposure and the cumulative previous damages (β_2). The cumulative damages are computed using the EM-DAT database from the the Centre for Research on the Epidemiology of Disasters (CRED). We select the 20 countries that are today part of the Euro area and keep the following disasters: extreme temperature, drought, flood, wildfire and storm. For the overall exposure score we create a monthly variable that is the sum over the following months (3, 6 or 12) of the damages generated by all these disasters and we re-scale by the GDP of the area. Regarding the 7 sub-scores, we matched each of them with the corresponding disasters (refer to Table 3). Regrettably, due to the lower frequency of certain events and the absence of particular disasters, we are only able to perform this assessment for 4 of the sub-scores.

Within our dataset, we have documented the presence of 188 natural disaster events recorded in the Euro Area. The mean financial losses per month, when at least one disaster takes place, amount to $2126.62 million. The most common occurrences are storms, with floods coming in a close second. On average, the most financially impactful disasters are those related to extreme temperatures.

The interaction term (β_3) is presented in Figure 5 when we consider the exposure as a

Table 3: Matched exposure score with corresponding disasters in the Euro Area

Exposure score	Corresponding disasters	Number of events[a]	Mean of damages[b]
Overall score	extreme temperature, drought, flood, wildfire, storm	188	2126.62
Average temperature	extreme temperature	32	6048.16
Rain intensity	flood	64	2734.02
Sea Level	flood	64	2734.02
Storm	storm	70	799.78

Note: [a] We only take into account events that have generated some damages. [b] The average damages per period where at least one disaster occured. Damages are expressed in millions dollars adjusted by the consumer price index.

continuous variable and in Figure 6 when we transform the score in a dummy based on the top-quartile to define highly exposed firms.

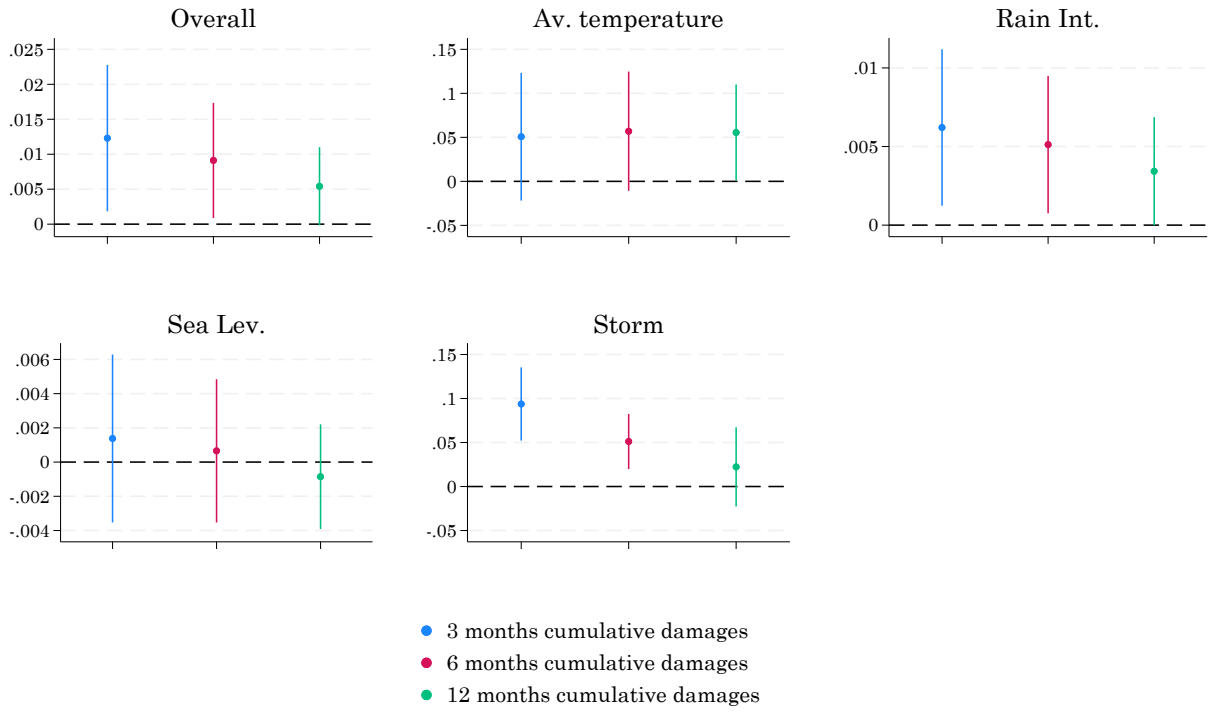
Figure 5, suggests the presence of a pattern. When examining the overall exposure as well as rain intensity and storm exposure, the interaction coefficient (β_3) is significant. However, it has a noticeable decreasing trend in significance as we extend the timeframe for evaluating the impact of cumulative damages. This pattern indicates that market pricing incorporates the associated risks notably in the 3 to 6 months following specific natural disaster events that caused damages. However, when assessing the 12-months period leading up to the damages, the significance of the interaction coefficient vanishes. It is worth noting that the coefficient's magnitude declines with times.

Additionally, we see than when considering the exposure as a continuous variable, there is no significant effect for the interaction between former damages and the average temperature exposure as well as the sea level exposure. The table corresponding to Figure 5 is available in Appendix (Table A4). To illustrate the impact for the overall score, for an average exposed firm in term of overall risk (26.5), an increase in one standard deviation in the 3 months prior cumulative damages (0.33) will result in an increase of the spread of 102 basis points[10], which represent 8.36% of the average spread. The same increase in the 6 months prior cumulative damages will results in an increase of the spread of about 76 basis points, which represent 6.23% of the average spread.

Focusing now on Figure 6 where the exposure is considered as a dummy variable based on the top-quartile, we note that the same pattern characterizes all of the sub-indicators (see Table A5). Indeed, in this configuration, for the average temperature and the sea level exposure we also have a significant and positive interaction with the prior damages associated. Subsequently, when introducing nonlinearities into the relationship and adopting a more stringent definition of exposure, we discover that all risks exhibit pricing adjustments following natural disaster events. However, this pricing effect is temporary, vanishing when we take into account the cumulative damages occurring over the one-year period preceding. Furthermore, when we extend the timeframe for assessing cumulative damages, the magnitude of the interaction shows a diminishing trend. To illustrate the effect concerning average temperature exposure, for a

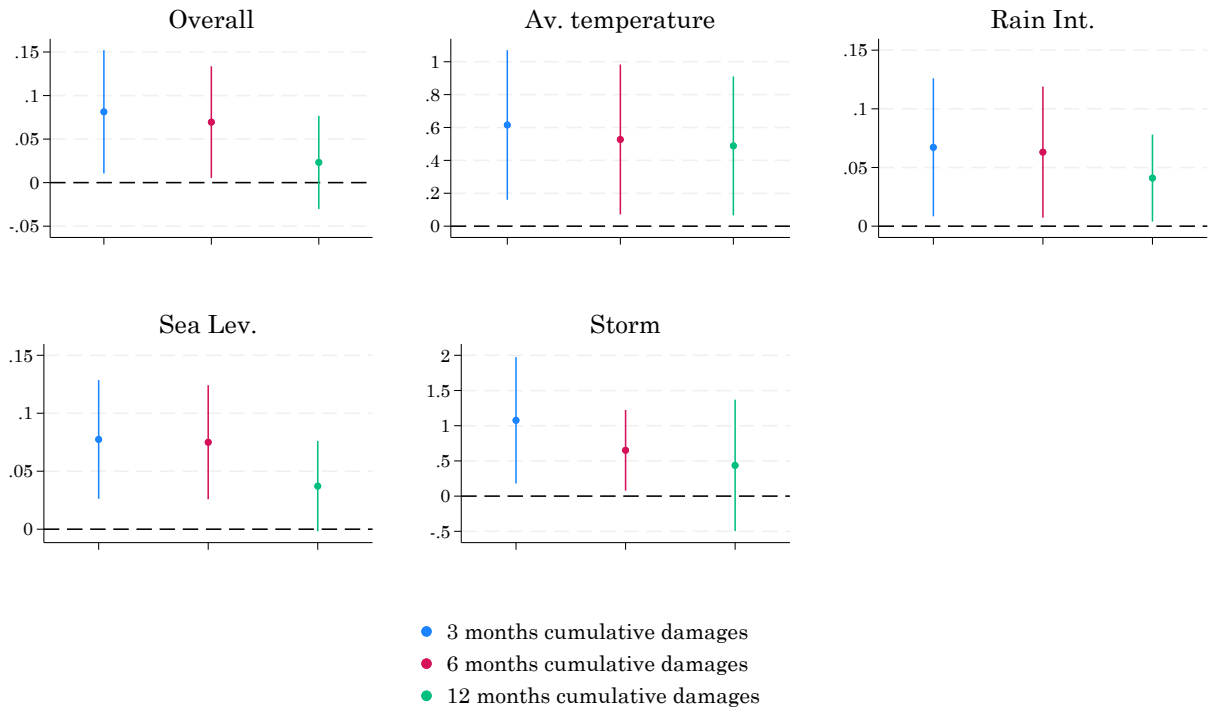
[10] $0.102 = 0.33 \times (-0.009 + 26.5 \times 0.012)$

Figure 5: Impact of former natural disasters on the spread according to the level of forward-looking exposure (continuous)



Note: This figure represent the interaction (β_3) between the exposure and the cumulative damages for the previous months (3 in blue, 6 in red and 12 in green). The coefficient are represented by the points and the line correspond to the confidence interval at 90%.

Figure 6: Impact of former natural disasters on the spread according to the level of forward-looking exposure (quartile)



Note: This figure represent the interaction (β_3) between the exposure and the cumulative damages for the previous months (3 in blue, 6 in red and 12 in green). The coefficient are represented by the points and the line correspond to the confidence interval at 90%.

company classified as being highly-exposed to this risk (falling within the top quartile), an increase of one standard deviation in the damages related to extreme temperatures in the preceding 3 months (0.45) results in an expansion of approximately 0.330 basis points in the spread. This expansion corresponds to 27% of the average spread.

Overall, it can be observed across all climate hazard risks that there exists a pricing response to the physical exposure of businesses following a natural disaster event resulting in damages. Nevertheless, investors appear to have a short memory, as the majority of the risk pricing vanishes for nearly all types of disasters when examining the accumulated damages spanning a one-year timeframe.

5.2 Proximity of the risk: domestic vs Eurozone

We go further into the analyse of the repricing effect by exploring whether it is exclusively happening after nearby events. It is conceivable that investor repricing takes place solely when an event directly impacts the country where the firm has its headquarter. Alternatively, we could anticipate that significant events occurring within the Euro area, even if they do not directly affect the firm's home country, could lead to revisions in beliefs.

To examine this hypothesis, we divided the previous damages variable into two categories: domestic damages and damages occurring in the rest of the Euro Area. Then our model is now composed of two interactive variables. We interact first the exposure score with a the prior

damages that happen in the Euro area deducting the damages in the home country of the firm if any (β_2). We add an interaction between the exposure score and the prior damages in the home country if any (β_3). Then, we estimate the following model:

$$\begin{aligned} Y_{i,t} = \beta_1 ExposureScore_j + \beta_2 ExposureScore_j \times \sum_{h=0}^{m} DamagesEAexcl._{i,t} \\ +\beta_3 ExposureScore_j \times \sum_{h=0}^{m} DamagesCountry_{i,t} + \beta_4 W_{i,t} + \beta_5 X_{j,t-1} + \beta_6 Z_{c,t-1} + FE + \varepsilon_{i,t} \end{aligned} \tag{3}$$

The dependant and the control variables remain the same and we still cluster standard errors at a firm level.

If the repricing of highly exposed firms is not only due to nearby risk we expect that the interaction between exposure score and the damages in the rest of Euro Area (β_2) will remain significant when adding a second interaction with domestic damages (β_3).

For this part of the analyse our attention will be directed towards the exposure score used as a binary variable. Since we have identified distinct nonlinear patterns in the impact based on the definition of exposure, employing the exposure score as a continuous variable might lead to misleading interpretations[11].

Looking at the results Table 4, we notice that non-realized risks (damages in the Euro Area) noticeably increase the bond risk for highly exposed firms, except for rain intensity exposure associated with flood damages. Interestingly, direct risks (damages in the firm's home country) appear to have an insignificant impact on raising the risk for highly exposed firms in almost all cases. These observations could potentially be clarified by the notion that rain intensity constitutes a highly localized risk. Consequently, even when a significant event takes place, its effects might not be widely applicable, leading to the observed results.

Furthermore, it is notable that the requirement for risk to be fully realized does not seem necessary, as damages incurred in other countries of the Euro Area are adequate to induce repricing effects. Moreover, the risk might not need to be truly realized as the damages caused in other country are sufficient to create a repricing. Nevertheless, this phenomenon appears to lack sustainability in the long run, leading us to deduce that investors tend to adopt a short-term perspective when it comes to this type of risk.

6 Robustness checks

6.1 After Paris Agreement

As stated by numerous paper (Ehlers et al., 2022; Carbone et al., 2021; Ginglinger and Moreau, 2019), the Paris Agreement has a pivotal role in the reevaluation of climate-related risks.

[11] You can still see the results when using exposure as a continuous variable in the Appendix Table A6. In the case of continuous exposure. The anticipated effect was observed exclusively in the context of storms, indicating that the repricing is influenced not only by national risks.

Table 4: The impact of home country natural disaster damages vs euro area damages according to the level of exposure (categorical)

	Overall	Av. Temp.	Rain Int.	Sea Lev.	Storm
Exposure score dummy	-0.008	0.117	-0.050	-0.124*	0.059
	(0.069)	(0.114)	(0.057)	(0.070)	(0.084)
— × cumulative damages 3m. Euro Area	0.088*	0.730*	0.053	0.091**	0.915*
	(0.045)	(0.383)	(0.047)	(0.037)	(0.538)
— × cumulative damages 3m. Country	0.029	0.154	0.036	-0.025	0.221
	(0.042)	(0.127)	(0.027)	(0.025)	(0.316)
Exposure score dummy	-0.015	0.110	-0.055	-0.129*	0.060
	(0.071)	(0.115)	(0.057)	(0.070)	(0.084)
— × cumulative damages 6m. Euro Area	0.078*	0.710*	0.048	0.089**	0.457
	(0.042)	(0.387)	(0.045)	(0.037)	(0.368)
— × cumulative damages 6m. Country	0.016	0.119	0.038	-0.025	0.055
	(0.037)	(0.119)	(0.028)	(0.024)	(0.399)
Exposure score dummy	-0.019	0.096	-0.061	-0.133*	0.056
	(0.069)	(0.115)	(0.056)	(0.070)	(0.100)
— × cumulative damages 12m. Euro Area	0.010	0.655*	0.014	0.040	-0.020
	(0.040)	(0.377)	(0.034)	(0.030)	(0.552)
— × cumulative damages 12m. Country	0.040	0.118	0.047*	0.003	0.331
	(0.044)	(0.111)	(0.026)	(0.038)	(0.394)
Controls variables	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓
N	30998	30998	30998	30998	30998
Number firms	115	115	115	115	115
Number bonds	666	666	666	666	666
R^2	0.717	0.719	0.717	0.719	0.717

Significance levels are: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Our paper does not primarily seek to quantify the precise impact of the Paris Agreement on the enhancement of risk pricing. Instead, our objective is to ascertain the presence of effective pricing mechanisms. Consequently, within this section, we examine the robustness of our findings within the context of the post-Paris Agreement, from November 2016 to December 2022. In Table A7, we propose a investigation on the pricing of physical risks post Paris-Agreement. The evidence of robust significant pricing remains elusive. Comparable outcomes emerge when examining pricing as a discrete variable categorized by quartiles, as depicted in Table A8. Notably, only the valuation of heat waves exposure appears to be robust.

We additionally examine whether in this setting natural events prompt a short-term reevaluation of more exposed companies if we focus solely on the period following the Paris Agreement. Observing Table A9, we notice that when considering the exposure to forward-looking physical risk as a continuous measure the results the outcomes retain their overall significance. Specifically, rain intensity and storm exposure exhibit continued statistical significance when considering cumulative damages over 3 and 6 months. However, it is noteworthy that the coefficients exhibit a higher magnitude. An increase of one standard deviation in the cumulative damages over the preceding 3 months (0.33) results in an amplified spread of 0.111 basis points for an averagely exposed firm concerning overall vulnerability, as opposed to the previous value of 0.102 basis points during the entire period. Furthermore, it's worth mentioning that the impact of 1-year cumulative prior damages is significant for overall vulnerability and rain intensity in the context of the post Paris-Agreement period, a phenomenon not observed when considering the all period. When considering the exposure as a categorical variable (see Table A10), we notice the same pattern of significance. Nevertheless, it is noteworthy that the impact magnitudes, with the exception of firms highly susceptible to average temperature rise risk, exhibit greater values during the post Paris-Agreement period.

Based on the insights gained from this robustness assessment, it can be deduced that the Paris Agreement did not substantially alter the European valuation of forward-looking physical risk. However, in terms of the reevaluation subsequent to natural disaster events, the impacts appear to exhibit a more pronounced magnitude.

6.2 Change in the exposure scenario and area considered for disasters measurement

As previously discussed in Section 3.2, the exposure calculations for firms are derived from the IPCC scenarios. In light of this, we proceed to investigate the stability of our findings by examining whether the results hold when employing the medium emissions scenario instead of the high emissions scenario. Examining Table A11 and A12, whether we analyze exposure as a continuous or categorical variable, we observe a pattern where only heat wave exposure consistently impacts the Euro Area bond market prices. Then, we assess the consistency of our second hypothesis regarding pricing adjustments following damages resulting from natural disasters in the Euro Area, using the intermediate scenario. Beginning with a focus on continuous exposure (Table A13), we observe that the outcomes for the cumulative periods of 3 and 6

months exhibit notable similarity in terms of both significance and magnitude across both scenarios. Nevertheless, when shifting attention to the 12-month period of cumulative damages, the interaction retains its significance for overall exposure and rain intensity exposure – a pattern not previously observed. Turning our attention to categorical exposure (Table A14), we find consistence in outcomes between the two scenarios, with one exception: the average temperature exposure loses its statistical significance. This outcome can be attributed to the fact that temperature rise is the physical event most closely tied to the emissions scenario.

Another avenue to explore in terms of robustness is the geographical area deemed influential for investors in the euro area bond market. Up until this point, our analysis has centered on damages incurred by disasters impacting the Euro Area (comprising 20 countries). However, in order to assess the durability of our findings, we opt to test our conclusions using damages caused by natural disasters within the broader context of the European Union (comprising 27 countries). Results are presented in Table A15 and Table A16. Remarkably, the results exhibit substantial consistency in both significance and extent when employing these two distinct geographical scopes for the natural disasters under consideration. The only small difference concern the interaction between the categorical storm exposure and the 6 months prior cumulative damages that lose its significance when considering the European Union.

Overall, our findings demonstrate a high degree of robustness when using a less severe scenario and expanding the geographical scope of natural disaster events under consideration.

6.3 Placebo natural disasters

The last avenue we decide to explore involve determining whether the repricing that follows significant natural disasters is genuinely attributable to these events. To assess this, we opted to perform placebo tests. In these tests, we randomly reallocate the events and their associated damages. Specifically, within the timeframe of 2014-2022, we introduce random alterations to the total monthly damages in the Euro Area. Subsequently, we proceed to compute cumulative sums over periods of 3, 6, and 12 months. Table A17 outlines the outcomes of the placebo tests performed with continuous exposure variables. We show that a significant portion of the time, our targeted interaction lacks significance or displays a noteworthy negative trend. These same trends persist when categorical exposure variables are employed, as demonstrated in Table A18. This deviation from our earlier findings underscores the conclusion that the substantial spread increase witnessed after events is not consistently replicated when events are randomly reassigned.

7 Conclusion

In this study, we conduct an empirical examination of how the Euro-zone bond market values firms' forward-looking physical risk. We use the CRIS database to gauge exposure to physical risk, utilizing both the sub-scores categorized by the type of physical risk and the overall score. Bond risk is assessed in terms of spread using as risk-free yield the ECB yield

curve on triple-A rated bonds. We employ a panel model that incorporates the conventional factors influencing bond spreads to specifically isolating the influence of future physical risk on the spread. Analyzing a dataset comprising 666 bonds, our findings do not strongly support the notion of a consistently accurate pricing of forward-looking physical risk during the period spanning from 2014 to 2022. The sole exception is the exposure to heat waves, which appears to be appropriately valued within the overall dataset. A one-standard deviation increase in heat wave exposure results in a 75% increase in the average spread. These findings are robust even after re-estimation following the Paris Agreement and when employing a different emissions scenario to calculate firms' exposure to physical risks.

Subsequently, we investigate whether the occurrence of natural disasters in the Euro Area affects the pricing of forward-looking physical risk. To gauge the visibility of these events, we use the monthly damages resulting from natural disasters in the region as a proxy. Globaly, our findings indicate that the spread increases for highly exposed firms following significant events. However, it's important to note that this adequate pricing effect is short-term and dissipates after one year. Notably, these conclusions do not hold as strongly for average temperature and sea level exposures when employing continuous exposure as a measure.

We demonstrate additionally that the influence of natural disaster events on bond pricing is not attributable to domestic damages but rather to more significant shocks at the Eurozone level. These shocks can affect perceptions even when the risk is not realized in the country where the firm is headquartered.

These outcomes, nonetheless, remain for the most part consistent when we conduct estimations solely after the Paris Agreement, apply a medium emissions scenario, and calculate natural disasters damages across the broader European Union (not limited to the Eurozone). Lastly, we validate the robustness of our findings by performing placebo estimations on the disaster variable. We randomly allocate these disasters across the time period to ensure that our results are not merely coincidental.

In sum, our assessment leads us to the conclusion that the pricing of physical risk is not currently a persistent element in firms' risk considerations. The increase of the awareness that followed significant events is of short-term nature. Nevertheless, given the rising frequency of large-scale natural disasters, this mispricing could potentially lead to significant destabilization in financial markets over time, as adjustments will become costlier.

References

Acharya, V. and Pedersen, L. (2005). Asset pricing with liquidity risk. *Journal of financial Economics*, 77(2):375–410.

Amiraslani, H., Lins, K., Servaes, H., and Tamayo, A. (2022). Trust, social capital, and the bond market benefits of ESG performance. *Review of Accounting Studies*, pages 1–42.

Basker, E. and Miranda, J. (2018). Taken by storm: Business financing and survival in the aftermath of hurricane katrina. *Journal of Economic Geography*, 18(6):1285–1313.

Bolton, P. and Kacperczyk, M. (2021). Do investors care about carbon risk? *Journal of financial economics*, 142(2):517–549.

Bourdeau-Brien, M. and Kryzanowski, L. (2020). Natural disasters and risk aversion. *Journal of Economic Behavior & Organization*, 177:818–835.

Campbell, J. and Taksler, G. (2003). Equity volatility and corporate bond yields. *The Journal of finance*, 58(6):2321–2350.

Carbone, S., Giuzio, M., Kapadia, S., Krämer, J. S., Nyholm, K., and Vozian, K. (2021). The low-carbon transition, climate commitments and firm credit risk. ECB Working Paper 2021/2631, European Central Bank.

Carvalho, V., Nirei, M., Saito, Y., and Tahbaz-Salehi, A. (2020). Supply chain disruptions: Evidence from the Great East Japan Earthquake. *The Quarterly Journal of Economics*, 136(2):1255–1321.

Chen, H., Joslin, S., and Tran, N.-K. (2012). Rare disasters and risk sharing with heterogeneous beliefs. *The Review of Financial Studies*, 25(7):2189–2224.

Christopoulos, A. (2021). The absolute roll measure. *Available at SSRN 3958079*.

Correa, R., He, A., Herpfer, C., and Lel, U. (2020). The rising tide lifts some interest rates: Climate change, natural disasters and loan pricing. *Natural Disasters and Loan Pricing (March 31, 2020)*.

Darmouni, O. and Papoutsi, M. (2022). The rise of bond financing in europe.

De Jong, F. and Driessen, J. (2012). Liquidity risk premia in corporate bond markets. *The Quarterly Journal of Finance*, 2(02):1250006.

Duffee, G. R. (1998). The relation between treasury yields and corporate bond yield spreads. *The Journal of Finance*, 53(6):2225–2241.

Ehlers, T., Packer, F., and De Greiff, K. (2022). The pricing of carbon risk in syndicated loans: Which risks are priced and why? *Journal of Banking & Finance*, 136:106180.

European Commission (2017). *Analysis of european corporate bond market*. The European Commission.

Fankhauser, S. and Tol, R. (2005). On climate change and economic growth. *Resource and Energy Economics*, 27(1):1–17.

Felbermayr, G. and Groschl, J. (2014). Naturally negative: The growth effects of natural disasters. *Journal of Development Economics*, 111:92 – 106. Special Issue: Imbalances in Economic Development.

Ginglinger, E. and Moreau, Q. (2019). Climate risk and capital structure. *Université Paris-Dauphine Research Paper*, (3327185).

Goldsmith-Pinkham, P., Gustafson, M. T., Lewis, R. C., and Schwert, M. (2022). Sea level rise exposure and municipal bond yields. Technical report, National Bureau of Economic Research.

Görgen, M., Jacob, A., Nerlinger, M., Riordan, R., Rohleder, M., and Wilkens, M. (2020). Carbon risk. *Available at SSRN 2930897*.

Hong, H., Li, F. W., and Xu, J. (2019). Climate risks and market efficiency. *Journal of econometrics*, 208(1):265–281.

Hosono, K., Miyakawa, D., Uchino, T., Hazama, M., Ono, A., Uchida, H., and Uesugi, I. (2016). Natural disasters, damage to banks, and firm investment. *International Economic Review*, 57(4):1335–1370.

Huynh, T. D., Nguyen, T. H., and Truong, C. (2020). Climate risk: The price of drought. *Journal of Corporate Finance*, 65:101750.

Huynh, T. D. and Xia, Y. (2021). Climate change news risk and corporate bond returns. *Journal of Financial and Quantitative Analysis*, 56(6):1985–2009.

King, T.-H. D. and Khang, K. (2005). On the importance of systematic risk factors in explaining the cross-section of corporate bond yield spreads. *Journal of Banking & Finance*, 29(12):3141–3158.

Kling, G., Volz, U., Murinde, V., and Ayas, S. (2021). The impact of climate vulnerability on firms' cost of capital and access to finance. *World Development*, 137:105131.

Kruttli, M. S., Roth Tran, B., and Watugala, S. W. (2021). Pricing poseidon: Extreme weather uncertainty and firm return dynamics.

Krylova, E. (2016). Determinants of euro-denominated corporate bond spreads.

Letta, M., Montalbano, P., and Pierre, G. (2022). Weather shocks, traders' expectations, and food prices. *American Journal of Agricultural Economics*, 104(3):1100–1119.

Lin, H., Wang, J., and Wu, C. (2011). Liquidity risk and expected corporate bond returns. *Journal of Financial Economics*, 99(3):628–650.

Malmendier, U. and Nagel, S. (2011). Depression babies: Do macroeconomic experiences affect risk taking? *The quarterly journal of economics*, 126(1):373–416.

Manela, A. and Moreira, A. (2017). News implied volatility and disaster concerns. *Journal of Financial Economics*, 123(1):137–162.

Merton, R. C. (1974). On the pricing of corporate debt: The risk structure of interest rates. *The Journal of finance*, 29(2):449–470.

Painter, M. (2020). An inconvenient cost: The effects of climate change on municipal bonds. *Journal of Financial Economics*, 135(2):468 – 482.

Safiullah, M., Kabir, M. N., and Miah, M. D. (2021). Carbon emissions and credit ratings. *Energy Economics*, 100:105330.

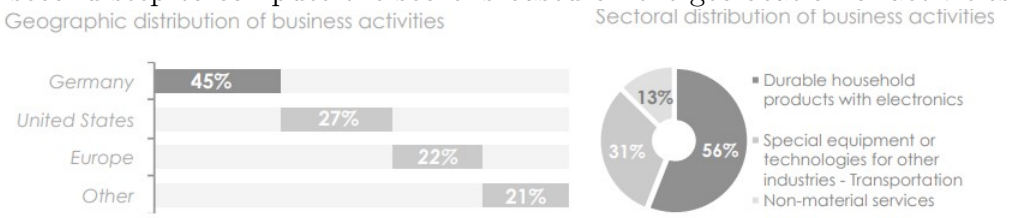
Seltzer, L. H., Starks, L., and Zhu, Q. (2022). Climate regulatory risk and corporate bonds. Technical report, National Bureau of Economic Research.

Stellner, C., Klein, C., and Zwergel, B. (2015). Corporate social responsibility and eurozone corporate bonds: The moderating role of country sustainability. *Journal of Banking & Finance*, 59:538–549.

Stroebel, J. and Wurgler, J. (2021). What do you think about climate finance?

A CRIS fictional firm example

To illustrate the construction of exposure scores we take the example provided in the CRIS guidebook of a fictional German multinational automotive corporation called LaVoitureDE.
The first step to compute the score is to identify the segment of operation of the firm. In this example the company operate mainly in the automotive industry (classified as industrial producing durable products with electronics within the CRIS classification). Then, according to the segment of operation vulnerability are identified. LaVoitureDE is more vulnerable to heavy rainfall, storms, and sea level rise.
The second step to compute the score is based on the geolocation of activities.



The company is mainly located in Europe. The locations are exposed to some intense hazard projections, but much less than some of its locations in Mexico and China, where detailed risk analysis should be run.
LaVoitureDE is assessed with a moderate risk rating (37) at a mid-term time horizon and for a medium emission scenario. The company faces a level of risk comparable to its sector, based on a sample of 25 companies.

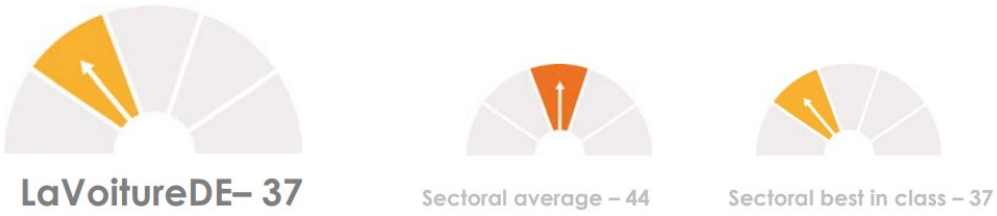
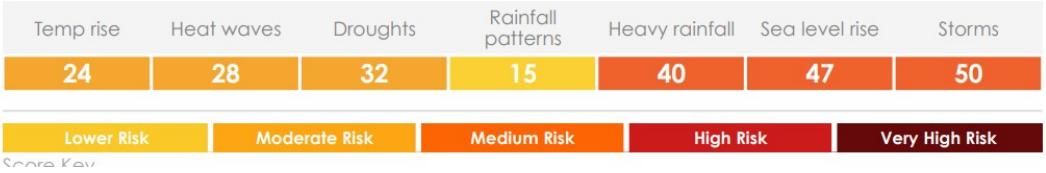


Figure 33 - Global risk rating and sectoral comparison for mid-term and medium-emission scenario



B Definition of variables

- **Monthly spread for a corporate bond**. Mid-yield of a bond minus the yield of the same maturity from the yield curve constructed by the European Central Bank (ECB) using Svensson model on all triple-A rating. Source: Datastream Refinitiv Eikon, European

Central Bank Data Portal.

- **Cumulative damages**. The cumulative damages are constructed as the sum of prior damages over the period considered (3, 6 or 12 months). Damages are constitutes of all damages and economic losses directly or indirectly related to the disaster. The information may include the breakdown figures by sectors: Social, Infrastructure, Production, Environment and other (when available). Source: EM-DAT from CRED, UCLouvain.

- **Logarithm of the amount issued**. The total amount to be raised by the issue of the Bond, in logarithm. Source: Datastream Refinitiv Eikon.

- **Year to maturity**. Using the maturity date, we compute the year to maturity as the maturity year minus the year of the current date. Source: Datastream Refinitiv Eikon.

- **Callable**. A binary variable that indicate if the bond is callable. Callable bonds are bonds whose contract allows the issuer to redeem them before the maturity date. Source: Datastream Refinitiv Eikon.

- **Coupon rate**. The coupon rate is the annual income an investor can expect to receive while holding a particular bond. It is fixed when the bond is issued and is calculated by dividing the sum of the annual coupon payments by the par value. Source: Datastream Refinitiv Eikon.

- **Credit rating**. Ratings aims at asses the level of creditworthiness of a bond, if missing we take the rating of the company. We use the information of the 3 majors rating agencies: S&P, Fitch and Moody's. We transform them into numerical values, with 1 corresponding to the lowest grade while 22 corresponds to the highest grade. Source: Datastream Refinitiv Eikon.

- **Absolute Roll measure of illiquidity**. Roll's measure estimates liquidity from correlations in price change. We computed using the following formula:

$$\hat{\lambda}_t = 2\sqrt{|-Cov(\Delta P_{t,j}, \Delta P_{t,j+1})|} \tag{A1}$$

  with $Cov(\Delta P_t, \Delta P_{t+1})$ the auto-covariance of price changes, we consider for each bond 20 training day j per month t. We take the absolute value following Christopoulos (2021) to preserve a maximum of our data. Source: Datastream Refinitiv Eikon.

- **Logarithm of total assets**. Total assets embody the valuation of all possessions owned by a company, a calculation achieved by summing up owner's equity and liabilities, in logarithm. Source: Datastream Refinitiv Eikon (WorldScope).

- **Leverage**. Leverage is calculated as the percentage of total debt to total equity. It reflects a company's capital arrangement, indicating the extent of debt within the blend of its debt and equity components. Source: Datastream Refinitiv Eikon.

Table A1: Ratings correspondance table

Rating score	S&P	Fitch	Moody's
22	AAA	AAA	Aaa
21	AA+	AA+	Aa1
20	AA	AA	Aa2
19	AA-	AA-	Aa3
18	A+	A+	A1
17	A	A	A2
16	A-	A-	A3
15	BBB+	BBB+	Baa1
14	BBB	BBB	Baa2
13	BBB-	BBB-	Baa3
12	BB+	BB+	Ba1
11	BB	BB	Ba2
10	BB-	BB-	Ba3
9	B+	B+	B1
8	B	B	B2
7	B-	B-	B3
6	CCC+	CCC+	Caa1
5	CCC	CCC	Caa2
4	CCC-	CCC-	Caa3
3	CC	CC	Ca
2	C	C	
1	D	D	C

- **Debt service capability**. Debt service capability is calculated by dividing Earnings Before Interest and Taxes (EBIT) by Interest Expense. This metric gauges the extent to which a company's earnings cover its interest obligations. Source: Datastream Refinitiv Eikon (WorldScope).

- **Cash to asset**. Cash to assets is computed as the amount of cash and equivalents divided by the current total assets. This ratio is a ratio of liquidity. Source: Datastream Refinitiv Eikon (WorldScope).

- **Operating profit margin** The operating profit margin is a ratio of profitability computed as the operating income over the net sales. Source: Datastream Refinitiv Eikon (WorldScope).

- **Tangibility**. This ratio signifies the proportion of tangible assets within the total assets. A higher ratio signifies a greater presence of tangible assets (or fixed assets) within the entirety of an entity's assets, while a lower ratio indicates the opposite. Source: Datastream Refinitiv Eikon (WorldScope).

- **Annual returns** We compute the annual returns of a firm by deducing the logarithm of price from the previous year to the logarithm of price of the current one. Source: Datastream Refinitiv Eikon.

- **Volatility of returns** Volatility is a statistical metric characterized by the annualized standard deviation of logarithmic price fluctuations. It quantifies the extent of variation across time. We computed monthly volatility using a moving window spanning one year. Source: Datastream Refinitiv Eikon.

- **CAPEX ratio**. The capex ratio is determined by dividing capital expenditures by net sales. This metric gauges the extent of a company's investments directed towards its future growth. Source: Datastream Refinitiv Eikon (WorldScope).

- **Carbon intensity**. To compute the carbon intensity we use the total emissions divided by the total revenue of the company. This carbon intensity allow us to gauge the amount of emissions for one unit or revenue. Datastream Refinitiv Eikon (Asset4 and WorldScope).

- **Lack of coping capacity**. It's a score going from 0 to 10, it relates to the ability of a country to cope with disasters in terms of formal, organized activities and the effort of the country's government as well as the existing infrastructure which contribute to the reduction of disaster risk. Source: IMF - Climate-driven INFORM Risk.

C Descriptive statistics

Table A2: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Spread	1.22	0.86	0.37	5.52	30998
Log. of issued amount	20.04	0.83	16.12	21.64	30998
Year to maturity	8.17	6.93	0	97	30998
Callable	0.61	0.49	0	1	30998
Coupon Rate	2.05	1.41	0	8.5	30998
Rating	14.58	1.85	2	20	30998
Illiquidity	0.26	0.26	0.01	1.59	30998
Log. of total assets	17.53	1.04	15.01	19.53	30998
Leverage	1.39	1.08	0.2	6.67	30998
Debt capability	8.42	10.45	-11.94	53.83	30998
Cash to assets	36.19	14.9	6.12	81.95	30998
Operating profit margin	11.28	11.44	-19.58	53.94	30998
Tangibility	0.27	0.17	0.01	0.77	30998
Annual returns	0	0.09	-0.13	0.3	30998
Volatility of returns	0.28	0.11	0	1.1	30998
CAPEX ratio	9.76	9.49	0.78	53.04	30998
Carbon intensity	0.03	0.04	0	0.2	30998

D Complementary tables

Table A3: Baseline results with exposure dummy based on quartile

	Overall score		Av.temperature		Heat waves		Droughts	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposure score dummy	0.023	0.095	0.211*	0.124	0.396***	0.298**	0.203	0.182
	(0.074)	(0.078)	(0.124)	(0.123)	(0.113)	(0.127)	(0.155)	(0.166)
R^2	0.697	0.714	0.701	0.714	0.709	0.719	0.699	0.714
	Rain Regime		Rain Intensity		Sea level		Storm	
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Exposure score dummy	-0.013	-0.050	-0.088	-0.058	-0.074	-0.053	-0.002	0.083
	(0.117)	(0.106)	(0.071)	(0.063)	(0.081)	(0.075)	(0.093)	(0.091)
R^2	0.696	0.713	0.698	0.713	0.697	0.713	0.696	0.713
Controls variables	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓	✓	✓	✓
Country FE		✓		✓		✓		✓
N	30998	30998	30998	30998	30998	30998	30998	30998
Number firms	115	115	115	115	115	115	115	115
Number bonds	666	666	666	666	666	666	666	666

Significance levels are: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table A4: Impact of natural disasters damages according to the level of exposure (continuous)

	Overall	Av. Temp.	Rain Int.	Sea Lev.	Storm
Exposure score	-0.009	0.004	-0.011	-0.008	-0.004
	(0.012)	(0.015)	(0.007)	(0.006)	(0.005)
— × cumulative damages 3m.	0.012*	0.051	0.006**	0.001	0.094***
	(0.006)	(0.044)	(0.003)	(0.003)	(0.025)
R^2	0.717	0.716	0.718	0.717	0.717
Exposure score	-0.009	0.003	-0.011	-0.007	-0.004
	(0.012)	(0.015)	(0.007)	(0.006)	(0.005)
— × cumulative damages 6m.	0.009*	0.057	0.005*	0.001	0.051**
	(0.005)	(0.041)	(0.003)	(0.003)	(0.019)
R^2	0.717	0.716	0.718	0.717	0.717
Exposure score	-0.010	0.002	-0.011	-0.007	-0.004
	(0.012)	(0.015)	(0.007)	(0.006)	(0.070)
— × cumulative damages 12m.	0.005	0.055*	0.003	-0.001	0.022
	(0.003)	(0.033)	(0.002)	(0.002)	(0.027)
R^2	0.717	0.717	0.718	0.717	0.716
Controls variables	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓
N	30998	30998	30998	30998	30998
Number firms	115	115	115	115	115
Number bonds	666	666	666	666	666
R^2	0.717	0.717	0.718	0.717	0.716

Significance levels are: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Table A5: Impact of natural disasters damages according to the level of exposure (dummy)

	Overall	Av. Temp.	Rain Int.	Sea Lev.	Storm
Exposure score dummy	-0.006	0.119	-0.050	-0.126*	0.058
	(0.069)	(0.114)	(0.057)	(0.069)	(0.083)
— × cumulative damages 3m.	0.081*	0.615**	0.067*	0.080**	1.076*
	(0.043)	(0.274)	(0.035)	(0.031)	(0.541)
R^2	0.716	0.718	0.717	0.718	0.717
Exposure score dummy	-0.014	0.115	-0.055	-0.132*	0.054
	(0.070)	(0.115)	(0.057)	(0.070)	(0.083)
— × cumulative damages 6m.	0.070*	0.527*	0.063*	0.075**	0.652*
	(0.039)	(0.275)	(0.030)	(0.029)	(0.345)
R^2	0.717	0.718	0.717	0.718	0.717
Exposure score dummy	-0.009	0.105	-0.058	-0.134*	0.046
	(0.069)	(0.115)	(0.055)	(0.070)	(0.098)
— × cumulative damages 12m.	0.023	0.488*	0.041*	0.037	0.437
	(0.032)	(0.255)	(0.022)	(0.024)	(0.563)
R^2	0.716	0.718	0.717	0.718	0.717
Controls variables	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓
N	30998	30998	30998	30998	30998
Number firms	115	115	115	115	115
Number bonds	666	666	666	666	666
R^2	0.716	0.718	0.717	0.718	0.717

Significance levels are: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Table A6: The impact of home country natural disaster damages vs euro area damages according to the level of exposure (continuous)

	Overall	Av. Temp.	Rain Int.	Sea Lev.	Storm
Exposure score	-0.009	0.004	-0.011	-0.007	-0.003
	(0.012)	(0.015)	(0.007)	(0.006)	(0.005)
— × cumulative damages 3m. Euro Area	0.011	-0.011	0.006	0.001	0.113***
	(0.007)	(0.056)	(0.004)	(0.003)	(0.032)
— × cumulative damages 3m. Country	0.006	0.034**	0.003	-0.000	-0.019*
	(0.004)	(0.014)	(0.003)	(0.002)	(0.010)
R^2	0.717	0.717	0.718	0.717	0.717
Exposure score	-0.010	0.003	-0.011	-0.007	-0.003
	(0.012)	(0.015)	(0.007)	(0.006)	(0.005)
— × cumulative damages 6m. Euro Area	0.007	0.001	0.004	0.001	0.066**
	(0.005)	(0.053)	(0.003)	(0.003)	(0.026)
— × cumulative damages 6m. Country	0.006	0.034**	0.003	-0.002	-0.027**
	(0.004)	(0.014)	(0.003)	(0.002)	(0.012)
R^2	0.717	0.717	0.718	0.717	0.717
Exposure score	-0.011	0.002	-0.012*	-0.007	-0.002
	(0.013)	(0.015)	(0.007)	(0.006)	(0.006)
— × cumulative damages 12m. Euro Area	0.002	-0.001	0.002	-0.001	0.020
	(0.004)	(0.043)	(0.003)	(0.002)	(0.029)
— × cumulative damages 12m. Country	0.007*	0.034***	0.004	-0.001	-0.023**
	(0.004)	(0.013)	(0.002)	(0.003)	(0.011)
R^2	0.717	0.718	0.718	0.717	0.717
Controls variables	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓
N	30998	30998	30998	30998	30998
Number firms	115	115	115	115	115
Number bonds	666	666	666	666	666
R^2	0.717	0.719	0.717	0.719	0.717

Significance levels are: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

E Robustness checks

E.1 After Paris Agreement

Table A7: Baseline results after Paris-Agreement (continuous exposure)

	Overall score		Av.temperature		Heat waves		Droughts	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposure score	-0.010	0.002	0.025	0.014	0.039***	0.025	0.014**	0.008
	(0.014)	(0.014)	(0.017)	(0.017)	(0.015)	(0.015)	(0.007)	(0.008)
R^2	0.708	0.723	0.710	0.724	0.715	0.725	0.710	0.724
	Rain Regime		Rain Intensity		Sea level		Storm	
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Exposure score	-0.020	-0.017	-0.012*	-0.009	-0.009	-0.005	-0.009*	0.002
	(0.021)	(0.021)	(0.007)	(0.008)	(0.006)	(0.006)	(0.005)	(0.006)
R^2	0.709	0.724	0.710	0.724	0.709	0.724	0.710	0.723
Controls variables	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓	✓	✓	✓
Country FE		✓		✓		✓		✓
N	27689	27689	27689	27689	27689	27689	27689	27689
Number firms	115	115	115	115	115	115	115	115
Number bonds	665	665	665	665	665	665	665	665

Significance levels are: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table A8: Baseline results after Paris-Agreement (categorical exposure)

	Overall score		Av.temperature		Heat waves		Droughts	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposure score	0.041	0.125	0.247*	0.159	0.383***	0.279**	0.179	0.153
	(0.081)	(0.079)	(0.129)	(0.126)	(0.115)	(0.131)	(0.156)	(0.169)
R^2	0.708	0.725	0.714	0.725	0.719	0.728	0.709	0.724
	Rain Regime		Rain Intensity		Sea level		Storm	
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Exposure score	0.001	-0.038	-0.082	-0.052	-0.052	-0.028	0.010	0.099
	(0.123)	(0.110)	(0.076)	(0.067)	(0.086)	(0.078)	(0.094)	(0.093)
R^2	0.707	0.723	0.708	0.723	0.708	0.723	0.707	0.724
Controls variables	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓	✓	✓	✓
Country FE		✓		✓		✓		✓
N	27689	27689	27689	27689	27689	27689	27689	27689
Number firms	115	115	115	115	115	115	115	115
Number bonds	665	665	665	665	665	665	665	665

Significance levels are: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table A9: After Paris Agreement - impact of natural disasters damages (continuous exposure)

	Overall	Av. Temp.	Rain Int.	Sea Lev.	Storm
Exposure score	-0.007	0.008	-0.009	-0.007	-0.003
	(0.013)	(0.015)	(0.007)	(0.006)	(0.006)
— × cumulative damages 3m.	0.013**	0.045	0.006**	0.001	0.104***
	(0.006)	(0.041)	(0.003)	(0.003)	(0.025)
R^2	0.728	0.728	0.729	0.729	0.728
Exposure score	-0.008	0.007	-0.009	-0.007	-0.003
	(0.013)	(0.015)	(0.007)	(0.006)	(0.006)
— × cumulative damages 6m.	0.010**	0.051	0.005*	0.001	0.058***
	(0.005)	(0.039)	(0.003)	(0.002)	(0.018)
R^2	0.728	0.728	0.729	0.729	0.728
Exposure score	-0.009	0.006	-0.009	-0.006	-0.004
	(0.013)	(0.015)	(0.007)	(0.006)	(0.007)
— × cumulative damages 12m.	0.006*	0.049	0.003*	-0.001	0.045
	(0.003)	(0.031)	(0.002)	(0.002)	(0.039)
R^2	0.728	0.728	0.729	0.729	0.728
Controls variables	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓
N	27689	27689	27689	27689	27689
Number firms	115	115	115	115	115
Number bonds	665	665	665	665	665

Significance levels are: * p < 0.10 ; ** p < 0.05 ; *** p < 0.01

Table A10: After Paris Agreement - impact of natural disasters damages (categorical exposure)

	Overall	Av. Temp.	Rain Int.	Sea Lev.	Storm
Exposure score dummy	0.010	0.156	-0.038	-0.101	0.068
	(0.069)	(0.117)	(0.060)	(0.071)	(0.085)
— × cumulative damages 3m.	0.084**	0.569**	0.070**	0.076**	1.079*
	(0.040)	(0.262)	(0.035)	(0.030)	(0.562)
R^2	0.728	0.730	0.728	0.729	0.729
Exposure score dummy	0.003	0.152	-0.043	-0.108	0.066
	(0.069)	(0.117)	(0.060)	(0.072)	(0.085)
— × cumulative damages 6m.	0.071*	0.486*	0.065*	0.074**	0.616*
	(0.037)	(0.270)	(0.034)	(0.029)	(0.324)
R^2	0.728	0.728	0.729	0.729	0.728
Exposure score dummy	0.006	0.142	-0.049	-0.109	0.042
	(0.068)	(0.117)	(0.058)	(0.071)	(0.109)
— × cumulative damages 12m.	0.029	0.437*	0.045**	0.035	0.687
	(0.030)	(0.253)	(0.022)	(0.023)	(0.828)
R^2	0.728	0.728	0.729	0.729	0.728
Controls variables	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓
N	27689	27689	27689	27689	27689
Number firms	115	115	115	115	115
Number bonds	665	665	665	665	665

Significance levels are: * p < 0.10 ; ** p < 0.05 ; *** p < 0.01

E.2 Change in the exposure scenario and area considered for disasters measurement

Table A11: Baseline results with medium scenario (continuous exposure)

	Overall score		Av.temperature		Heat waves		Droughts	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposure score	-0.010	0.002	0.023	0.007	0.033**	0.024*	0.017**	0.011
	(0.014)	(0.014)	(0.018)	(0.018)	(0.015)	(0.014)	(0.007)	(0.007)
R^2	0.697	0.713	0.698	0.713	0.702	0.715	0.700	0.714
	Rain Regime		Rain Intensity		Sea level		Storm	
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Exposure score	-0.028	-0.021	-0.011	-0.009	-0.009	-0.005	-0.009*	0.000
	(0.029)	(0.029)	(0.007)	(0.007)	(0.006)	(0.006)	(0.005)	(0.006)
R^2	0.700	0.714	0.698	0.714	0.699	0.713	0.700	0.713
Controls variables	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓	✓	✓	✓
Country FE		✓		✓		✓		✓
N	30998	30998	30998	30998	30998	30998	30998	30998
Number firms	115	115	115	115	115	115	115	115
Number bonds	666	666	666	666	666	666	666	666

Significance levels are: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table A12: Baseline results with medium scenario (categorical exposure)

	Overall score		Av.temperature		Heat waves		Droughts	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposure score dummy	0.037	0.101	0.126	-0.052	0.406***	0.328**	0.179	0.157
	(0.074)	(0.080)	(0.138)	(0.137)	(0.121)	(0.129)	(0.150)	(0.156)
R^2	0.697	0.714	0.698	0.713	0.709	0.720	0.698	0.714
	Rain Regime		Rain Intensity		Sea level		Storm	
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Exposure score dummy	-0.154	-0.212**	-0.121*	-0.090	-0.074	-0.053	-0.002	0.083
	(0.105)	(0.099)	(0.062)	(0.056)	(0.081)	(0.075)	(0.093)	(0.091)
R^2	0.700	0.718	0.699	0.714	0.697	0.713	0.696	0.713
Controls variables	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓	✓	✓	✓
Country FE		✓		✓		✓		✓
N	30998	30998	30998	30998	30998	30998	30998	30998
Number firms	115	115	115	115	115	115	115	115
Number bonds	666	666	666	666	666	666	666	666

Significance levels are: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table A13: Medium scenario - impact of natural disasters damages (continuous exposure)

	Overall	Av. Temp.	Rain Int.	Sea Lev.	Storm
Exposure score	-0.008	0.001	-0.010	-0.007	-0.004
	(0.013)	(0.017)	(0.007)	(0.006)	(0.005)
— × cumulative damages 3m.	0.013**	0.056	0.006**	0.002	0.094***
	(0.006)	(0.050)	(0.003)	(0.003)	(0.025)
R^2	0.717	0.716	0.718	0.717	0.717
Exposure score	-0.009	0.000	-0.011	-0.007	-0.004
	(0.013)	(0.017)	(0.007)	(0.006)	(0.005)
— × cumulative damages 6m.	0.010*	0.067	0.005**	0.001	0.051***
	(0.005)	(0.046)	(0.002)	(0.003)	(0.019)
R^2	0.717	0.716	0.718	0.717	0.717
Exposure score	-0.009	-0.001	-0.011	-0.007	-0.004
	(0.013)	(0.017)	(0.007)	(0.006)	(0.006)
— × cumulative damages 12m.	0.006*	0.063*	0.004*	-0.001	0.022
	(0.004)	(0.038)	(0.002)	(0.002)	(0.027)
R^2	0.717	0.717	0.718	0.717	0.716
Controls variables	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓
N	30998	30998	30998	30998	30998

Significance levels are: * p < 0.10 ; ** p < 0.05 ; *** p < 0.01

Table A14: Medium scenario - impact of natural disasters damages (categorical exposure)

	Overall	Av. Temp.	Rain Int.	Sea Lev.	Storm
Exposure score dummy	-0.005	-0.026	-0.074	-0.126*	0.058
	(0.070)	(0.131)	(0.049)	(0.069)	(0.083)
— × cumulative damages 3m.	0.102**	0.457	0.083**	0.077**	1.076**
	(0.042)	(0.290)	(0.034)	(0.031)	(0.541)
R^2	0.717	0.716	0.717	0.718	0.717
Exposure score dummy	-0.014	-0.029	-0.080	-0.132*	0.054
	(0.071)	(0.132)	(0.049)	(0.070)	(0.083)
— × cumulative damages 6m.	0.086**	0.371	0.077**	0.075**	0.652*
	(0.038)	(0.294)	(0.032)	(0.030)	(0.345)
R^2	0.717	0.716	0.717	0.718	0.717
Exposure score dummy	-0.007	-0.036	-0.082*	-0.134*	0.046
	(0.071)	(0.133)	(0.047)	(0.070)	(0.098)
— × cumulative damages 12m.	0.027	0.318	0.042*	0.037	0.437
	(0.032)	(0.273)	(0.022)	(0.024)	(0.563)
R^2	0.716	0.716	0.717	0.718	0.717
Controls variables	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓

Significance levels are: * p < 0.10 ; ** p < 0.05 ; *** p < 0.01

Table A15: European Union damages - impact of natural disasters damages (continuous exposure)

	Overall	Av. Temp.	Rain Int.	Sea Lev.	Storm
Exposure score	-0.009	0.004	-0.011	-0.008	-0.004
	(0.012)	(0.015)	(0.007)	(0.006)	(0.005)
— × cumulative damages 3m.	0.014*	0.060	0.007**	0.002	0.120***
	(0.007)	(0.051)	(0.004)	(0.003)	(0.035)
R^2	0.717	0.716	0.718	0.717	0.717
Exposure score	-0.009	0.003	-0.011	-0.007	-0.004
	(0.012)	(0.015)	(0.007)	(0.006)	(0.005)
— × cumulative damages 6m.	0.011*	0.067	0.006*	0.001	0.073**
	(0.006)	(0.048)	(0.003)	(0.003)	(0.028)
R^2	0.717	0.716	0.718	0.717	0.717
Exposure score	-0.010	0.002	-0.011	-0.007	-0.004
	(0.012)	(0.015)	(0.007)	(0.006)	(0.006)
— × cumulative damages 12m.	0.006	0.065*	0.004	-0.001	0.037
	(0.004)	(0.039)	(0.002)	(0.002)	(0.033)
R^2	0.717	0.717	0.718	0.717	0.716
Controls variables	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓

Significance levels are: * p < 0.10 ; ** p < 0.05 ; *** p < 0.01

Table A16: European Union damages - impact of natural disasters damages (categorical exposure)

	Overall	Av. Temp.	Rain Int.	Sea Lev.	Storm
Exposure score	-0.006	0.119	-0.050	-0.126*	0.056
	(0.069)	(0.114)	(0.057)	(0.069)	(0.084)
— × cumulative damages 3m.	0.095*	0.722**	0.079*	0.091**	1.230*
	(0.050)	(0.322)	(0.042)	(0.036)	(0.740)
R^2	0.716	0.718	0.717	0.718	0.717
Exposure score	-0.014	0.115	-0.055	-0.132*	0.050
	(0.070)	(0.115)	(0.057)	(0.070)	(0.085)
— × cumulative damages 6m.	0.081*	0.619*	0.074*	0.088**	0.835
	(0.045)	(0.322)	(0.039)	(0.035)	(0.513)
R^2	0.717	0.718	0.717	0.718	0.717
Exposure score	-0.009	0.105	-0.059	-0.134*	0.039
	(0.069)	(0.115)	(0.055)	(0.070)	(0.100)
— × cumulative damages 12m.	0.028	0.573*	0.048*	0.043	0.563
	(0.037)	(0.299)	(0.026)	(0.028)	(0.655)
R^2	0.716	0.718	0.717	0.718	0.717
Controls variables	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓

Significance levels are: * p < 0.10 ; ** p < 0.05 ; *** p < 0.01

E.3 Placebo natural disasters

Table A17: Placebos - impact of natural disasters damages (continuous exposure)

	Overall	Av. Temp.	Rain Int.	Sea Lev.	Storm
Exposure score	-0.005	0.004	-0.009	-0.007	-0.002
	(0.012)	(0.015)	(0.007)	(0.005)	(0.005)
— × cumulative damages 3m.	-0.015*	0.048	-0.009**	-0.003	-0.044***
	(0.008)	(0.042)	(0.004)	(0.004)	(0.014)
R^2	0.717	0.716	0.718	0.717	0.716
Exposure score	-0.004	0.004	-0.008	-0.007	-0.002
	(0.012)	(0.015)	(0.007)	(0.006)	(0.005)
— × cumulative damages 6m.	-0.014**	0.053	-0.009**	-0.002	-0.012
	(0.007)	(0.037)	(0.004)	(0.003)	(0.014)
R^2	0.717	0.716	0.718	0.717	0.716
Exposure score	-0.003	0.004	-0.007	-0.007	-0.002
	(0.012)	(0.015)	(0.007)	(0.006)	(0.006)
— × cumulative damages 12m.	-0.010**	0.048	-0.008***	-0.001	-0.008
	(0.004)	(0.029)	(0.002)	(0.002)	(0.017)
R^2	0.717	0.716	0.719	0.717	0.716
Controls variables	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓
N	30998	30998	30998	30998	30998
Number firms	115	115	115	115	115
Number bonds	666	666	666	666	666

Significance levels are: * p < 0.10 ; ** p < 0.05 ; *** p < 0.01

Table A18: Palcebos - impact of natural disasters damages (categorical exposure)

	Overall	Av. Temp.	Rain Int.	Sea Lev.	Storm
Exposure score	0.014	0.124	-0.036	-0.114	0.077
	(0.068)	(0.115)	(0.057)	(0.069)	(0.086)
— × cumulative damages 3m.	-0.096***	0.255	-0.091**	-0.053	-0.417
	(0.034)	(0.267)	(0.035)	(0.036)	(0.408)
R^2	0.716	0.718	0.717	0.718	0.717
Exposure score	0.022	0.123	-0.027	-0.111	0.079
	(0.068)	(0.115)	(0.057)	(0.069)	(0.088)
— × cumulative damages 6m.	-0.085**	0.200	-0.091**	-0.041	-0.314
	(0.035)	(0.252)	(0.040)	(0.039)	(0.483)
R^2	0.717	0.718	0.717	0.718	0.717
Exposure score	0.022	0.125	-0.014	-0.111	0.081
	(0.070)	(0.116)	(0.058)	(0.071)	(0.088)
— × cumulative damages 12m.	-0.043	0.014	-0.087**	-0.021	-0.195
	(0.029)	(0.265)	(0.034)	(0.030)	(0.478)
R^2	0.716	0.718	0.717	0.718	0.717
Controls variables	YES	YES	YES	YES	YES
Time FE	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓
N	30998	30998	30998	30998	30998
Number firms	115	115	115	115	115
Number bonds	666	666	666	666	666

Significance levels are: * p < 0.10 ; ** p < 0.05 ; *** p < 0.01