



The impact and the contagion effect of natural disasters on sovereign credit risk. An empirical investigation

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ABSTRACT

This paper investigates the relationship between natural disasters and the reaction of sovereign CDS spread in Europe. By applying an event study methodology during the period January 2007–December 2021 on an original database in which we identify 92 natural disasters in 17 European countries, we assess the reaction of the sovereign CDS market to a natural disaster. We find a heterogeneous response of the European sovereign risk to a natural disaster, as the response of the sovereign CDS market differs from region to region. The advent of a natural disaster can increase inequality between the regions due to the higher cost of credit for sovereigns and the reduced scope for manoeuvring public finances. Also, the results of the contagion effect confirm the hypothesis of a cross-border propagation effect, as natural disaster, in general, is not local event but spreads to other countries.

1. Introduction

The advent of a natural disaster has a disruptive effect on several channels. First and foremost, a natural disaster causes the loss of human life and the consequent loss of human capital. Second, natural disasters produce damage to physical capital with the destruction of houses, vehicles and infrastructures. Third, there is an out-migration flow with people trying to reach a safer place to restart their life. All this together leads to a disruption of economic activity and the need to create a new equilibrium.

In the last ten years, climate change has impacted the financial markets and has undermined financial stability (Giuzio et al., 2019; Pagnottoni, Spelta, Flori, & Pammolli, 2022). The advent of a natural disaster related to climate change is an event that, unfortunately, impacts the financial markets and real economics (Mallucci, 2022; Pagnottoni et al., 2022). Climate change and the consequent extreme weather have often heavily impacted the real economy of small agricultural countries. The nexus between natural disasters and sovereign risk is more visible in countries whose economy is focused on agriculture because extreme weather events first impact this sector.

After the occurrence of natural disasters, the sovereign entity is called upon to intervene with investments aimed at helping people and rebuilding the country. The prospect of huge investments necessary for

the reconstruction of the country inevitably increases the sovereign debt making it less sustainable in the long and short term and increasing, in some cases, the probability of the country defaulting.

This paper aims to investigate how the advent of a natural disaster impacts the European country's risk. We investigate the immediate impact of European natural disasters in 17 European countries on sovereign credit risk over the period 2007 to 2021. We apply an event study methodology which enables us to understand the reaction of the CDS market to a natural disaster. We assess the effects of different subgroups of natural disasters, namely climatological, extra-terrestrial geophysical, hydrological, and meteorological. This permits to capture of which events have a large and widespread effect on the country's risk at a European level. Furthermore, the applied methodology allows us to assess the effects of natural disasters from a regional perspective to identify the regions more exposed to the inception of natural disasters and thus, evaluate whether the climate change mitigation actions undertaken by the individual regions are sufficient and efficient to prevent financial stability. Conceptually, CDS spreads have certain advantages for analysing countries' credit, liquidity and creditworthiness risk. CDS spreads are more responsive to information on the underlying credit quality of the issuer. Therefore, they can be interpreted as a forward-looking market indicator of sovereign credit risk. According to Calice, Mio, Stërba, and Vašíček (2015), CDS spread captures investors'

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assessment of the probability that the country will suffer an immediate financial crisis. Natural disasters may affect the government's ability to raise capital to finance its short-term activities. Therefore, such adverse events negatively affect the government's liquidity position in the short-term (Klomp, 2015). This liquidity risk may turn into a sovereign default: the government will no longer be able to meet its debt repayment obligations in the face of increased pressures on the sovereign bond market (an increase of interest rate). Hence, we consider CDS spreads as our survey variable because it allows us to capture the immediate country's liquidity risk that may plunge into a default crisis.

The paper contributes to the literature on climate change's impact on the financial markets in several ways. First, to the best of our knowledge, this is the first paper examining the short-term impact of natural disasters on the country's risk in the European context. Previous works (e.g., Bourdeau-Brien & Kryzanowski, 2017; Ferreira & Karali, 2015; Lanfear, Lioui, & Siebert, 2019; Pagnottoni et al., 2022) have highlighted the heterogeneity of stock market responses to natural extreme events. We, in this research, capture the effects of natural disasters on country risk, i.e., the risk that a natural disaster may affect public finances, hence the government's ability to repay its debtors (namely the credit risk). As the literature points out (Mallucci, 2022; Noy & Nualsri, 2011; Zenios, 2022), there are two main channels through which natural disasters affect public finances: 1) reduced government revenue and 2) increased pressure on public spending (Klomp, 2015). Therefore, assessing the effects of natural disasters on a country's credit risk is vital in the current climate crisis context. Second, we test the reaction of the sovereign CDS market to several types of natural disasters (climatological, extra-terrestrial, geophysical, hydrological, and meteorological). This distinction allows us to capture the difference in the impacts of natural disasters to see which natural event can convey the most significant risk, hence the greatest financial cost. Third, we assess the contagion effect to evaluate whether a natural disaster event can spread from one country to another country. Compared to the existing literature (Klomp, 2015; Mallucci, 2022), our method allows us to assess the contagion effects of a natural event affecting one economic-financial system on the other. We provide information on the propagation effects of credit risk. Our estimates consider the direct effect and include interactions between countries, which are necessary components for a proper assessment of credit risk transmission due to natural disaster events. The understanding of such effects will be a useful warning for local political authorities called upon to manage the economic and social crisis resulting from a natural disaster.

The remainder of the study is organized as follows. In the next section, we review the relevant literature and develop the research hypotheses. Sections 3 and 4 present the methodology and the data. The empirical results are reported in Section 5, 6 and 7. In Section 8, we draw the conclusion.

2. Literature review

The focus on the climate change crisis has triggered a growing literature to study and measure the financial and economic stability (resilience) of countries (or firms) affected by natural disasters (Albuquerque & Rajhi, 2019; Klomp, 2014; Mallucci, 2022; Noth & Schüwer, 2018; Panwar & Sen, 2019). However, few kinds of research have focused on the effect of natural disasters on financial markets.

Pioneering work is the paper by Worthington and Valadkhani (2004) which examines the impact of natural disasters on the Australian capital market from 1982 to 2002. Using the methodology of intervention analysis, the authors find how the shock caused by natural disasters strongly affects Australian market stock returns. Lee, Wu, and Wang (2007) analyse the impact of the 2004 Southeast Asian tsunami on 26 international stock indexes and exchange rates. Their results show that the shock had more of an impact on the domestic financial market in the Asian region, i.e., there was no contagion effect between financial markets.

Wang and Kutan (2013) investigate the impact of natural disasters on the insurance industry in the Japanese and U.S. markets using the multivariate GARCH methodology. Their findings highlight how natural events significantly affect the insurance industry, in contrast to composite financial indices. The authors document heterogeneity in the effects, showing how such extreme events can positively or negatively affect stock returns. The same results are highlighted by Ferreira and Karali (2015). Using the regression-based event study approach, the authors analyse the response of market returns and volatility of aggregate market indices in 35 financial markets to earthquakes from 1994 to 2013. Their findings indicate how resilient global financial markets are to shocks caused by earthquakes. The results show that only the volatility of the Japanese financial market is affected by earthquakes. To this end, focusing on the 2011 Japanese earthquake, Valizadeh, Karali, and Ferreira (2017) show how this extreme event affected 19 international stock markets. By the event study framework, the authors find heterogeneous effects among Japanese financial sectors, highlighting how some of them benefited. These results are also confirmed by Fakhry, Aktan, Masood, Tvaronavičienė, and Celik (2018). The authors with the C-GARCH model show the significant short-lived impact of the 2011 tsunami on the volatility of the Nikkei 225 index.

Focusing on the effects of hurricanes in the U.S. context, Lanfear et al. (2019) analyse the dynamics of the financial market in correspondence with such weather events. To this end, the authors use the event study model on all common stocks traded on the NYSE, NYSE MKT, and NASDAQ between January 1990 and December 2017. The authors document the existence of abnormal effects on the financial market, finding that high momentum and growth stocks are the most susceptible stocks (negative return) in the vicinity of extreme natural events such as hurricanes.

More recently, Pagnottoni et al. (2022) studied the effects of natural disasters classified as biological, climatological, geophysical, hydrological and meteorological on 27 stock market indices during the period 2001–2019. Using the event study methodology, the authors find heterogeneous impacts of natural hazard shocks on stock markets. In particular, their results show how biological catastrophes positively impact financial markets while climatic catastrophes have a negative effect.

Our work is close to Klomp's (2015) paper, which unlike the literature highlighted above, shifts the focus of the analysis to sovereign risks. The author analyses how natural disasters can impact emerging market sovereign risk during 1999–2010. By a heterogeneous dynamic panel, the author finds how natural events have a significant short- and long-run impact on credit default spread, i.e., significantly increasing the sovereign default premium.

Our paper contributes to this literature by analysing the impact of natural disasters (climatological, extra-terrestrial, geophysical, hydrological, and meteorological) on sovereign risk in the European context. Using the event study approach, we can quantify these effects and how they propagate to other economic-financial systems (contagion effect). This allows us to assess the impacts of natural disasters on a country's credit risk and contagion effects. Such an assessment is of vital importance in the current climate crisis context. Following the previous literature, we can state the following research hypotheses:

Hypothesis 1. *A natural disaster increases the sovereign CDS market.*

Hypothesis 2: *"Inequality effect" - A natural disaster increases financial inequality between countries.*

Hypothesis 3. *The reaction of sovereign CDS spreads differs from the type of natural disaster.*

Hypothesis 4: *"Cross-border propagation effect" - A natural disaster spreads from one country to another country.*

3. Methodology

To assess the short-term reaction of the sovereign CDS market to a natural disaster, we apply an event study methodology (MacKinlay, 1997) allowing us to understand the size and the direction of the country's risk reaction to the advent of a natural disaster. We define a natural disaster, an exogenous shock, as the "event" and we estimate the market model based on CDS spreads changes in several event windows.¹ The sovereign CDS spreads changes are calculated using the following market model:

$$AR_{it} = R_{it} - (\alpha_i + \beta_i R_{mt}) \quad (1)$$

where AR_{it} is the abnormal CDS change that is the difference between the observed changes and the expected changes for each country over the different event windows, R_{it} is the observed sovereign CDS change² and $(\alpha_i + \beta_i R_{mt})$ is the expected change estimated for each event. To estimate the market return, R_{mt} , we use Datastream Europe 5 Year CDS index as a proxy for the CDS market (Andrieş, Ongena, & Sprincean, 2021; Dell'Atti, di Tommaso, & Pacelli, 2022).

The event study is performed over an estimated window of 150 trading days, i.e. $[-150; 0]$ where $t = 0$ is the event day. For each event window, we carry out OLS estimates of daily CDS spreads changes and aggregate them to estimate the cumulative abnormal returns (CAR) in each event window. Finally, we carry out two different non-parametric tests: bootstrapped standard errors and the Wilcoxon test to assess if the reaction of the country's risk to a natural disaster is, on average, significantly different from zero.

To further investigate the impact of natural disasters on the sovereign CDS market, we run a second set of analyses in which we evaluate the contagion effect of a natural disaster. The occurrence of a natural disaster in a country may propagate to other countries because they are geographically near to the country in which the natural disasters occur or because of commercial or financial interlinkages. Indeed, the country may be exposed to other countries' natural disasters because of the import and export or because banks hold assets, especially government bonds, of the country in which the event occurs. To run this analysis, we first construct a dummy variable, called *Contagion*, taking the value of one in countries in which the natural disaster does not occur and on the date in which a natural disaster occurs in another country and zero otherwise. For example, an event occurs in Austria on 17/January/2007. The *contagion* variable has the value of 1 in all other countries in the sample less than Austria on the date 17/January/2007. However, to avoid biased estimates, we substitute the value of zero to the dummy variable if two natural disasters occur in two different countries in the horizon time of 10 days. After the construction of this variable, we run the event study model in Eq. (1) to assess if there is a cross-border contagion effect in a short time. A positive or negative coefficient statistically significant would imply the presence of a cross-border contagion effect whereas a positive or negative coefficient not statistically significant would imply that the natural disasters are local events not able to affect the risk of the country not affected by the natural disaster. A positive coefficient implies that the advent of a natural disaster would increase the sovereign risk of the other countries and thus, there is a cross-border propagation effect. On the contrary, a negative one implies that the risk of the country not being affected by natural disasters declines.

4. Data

To construct the data set, we first identify all the natural disasters

that have occurred during the period January 2007–December 2021 on the EM-DAT public³ database in which we identify 365 natural disasters divided into 5 Disaster Subgroups: climatological, extra-terrestrial, geophysical, hydrological, and meteorological⁴ in 27 European countries.⁵ Next, following Klomp (2014) and Gassebner, Keck, and Teh (2010), we consider only the events that have direct and widespread damage to the economy and financial system in a country. Therefore, we include only the "big" events, and we exclude the local ones. Specifically, the events that are in our sample are those that have caused estimated damage not lower than 1 % of the GDP of the country. By establishing this criterion to select the events, the total number of natural disasters reduces. This process yields a data set that includes 92 natural disasters in 17 EU countries⁶ over the period January 2007–December 2021. To further investigate the impact of natural disasters on the sovereign CDS spreads, we divided the countries into 4 regions: Eastern, Northern, Southern and Western Europe. Specifically, Eastern Europe includes the Czech Republic, Poland, Romania, and Russia; Northern Europe includes Ireland, and Norway; Southern Europe includes Croatia, Greece, Italy, Portugal, Slovenia and Spain and, finally, Western Europe includes Austria, Belgium, France, Germany, and the Netherlands.

As reported in Table 1, 45.65% of natural disasters are hydrological, 34.78% meteorological, 7.61% geophysical, 10.87% climatological, and 1.09% extra-terrestrial. The regions that have registered the maximum number of natural disasters during the sample period are Southern and Western Europe with 40 and 29 events, respectively. The distribution of natural disasters by year is reported in Fig. 1. The distribution of the natural disasters divided by subgroups and countries is reported in Table A1 in Appendix.

To measure the country risk, we use 5-year CDS mid-quotes on senior unsecured debt contracts sourced by Thomson Reuters Datastream, which are generally considered to be the most liquid contracts and represent the largest share of the CDS market (Ballester, Casu, & González-Urteaga, 2016). The summary statistics of sovereign CDS spreads divided by country are reported in the appendix (Table A2).

5. Results

5.1. The impact of natural disasters on the sovereign CDS market

The results of the event study are reported in Table 2. For the full sample (Panel A of Table 2), we find empirical evidence against our first hypothesis that natural disasters are events that are relevant to sovereign risk. Specifically, the sovereign risk increases when a natural disaster occurs implying that there is a cost associated with physical risk discounted in terms of worst sovereign risk. The reaction of the CDS market to natural disasters disappears after 10 trading days. Hence, we can consider the $[0, +15]$ event window as the tipping point of effects. These findings suggest the short-term impact of natural disasters on CDS change. In fact, we can see that the response of the CDS market to a natural disaster is bigger in the event windows $[0; +10]$ than in the following event windows. Indeed, the sovereign risk increases by 0.38%

³ <https://public.emdat.be/data>

⁴ Climatological events include drought, glacial lake outburst and wildfire. Extra-terrestrial events comprise impact and space weather events. Geophysical events include earthquakes, volcanic activity and mass movement. Hydrological events are floods, landslides and wave action, whereas meteorological events are storms, extreme temperatures and fog.

⁵ Austria, Belgium, Croatia, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, and Sweden.

⁶ Austria, Belgium, Croatia, Czech Republic, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slovenia, and Spain.

¹ $[0, +15]$, $[0, +10]$, $[0, +5]$, $[0, +3]$, $[0, +2]$ and $[0, +1]$.

² According to Pagnottoni et al., (2022), R_{it} shows the long-run change of the CDS aggregate market.

Table 1
Distribution of natural disasters by regions.

Country	# of natural disaster					Total
	Climatological	Extra-terrestrial	Geophysical	Hydrological	Meteorological	
Eastern Europe	4	1	1	11	4	21
Northern Europe	–	–	–	2	–	2
Southern Europe	6	–	6	19	9	40
Western Europe	–	–	–	10	19	29
Total	10	1	7	42	32	92

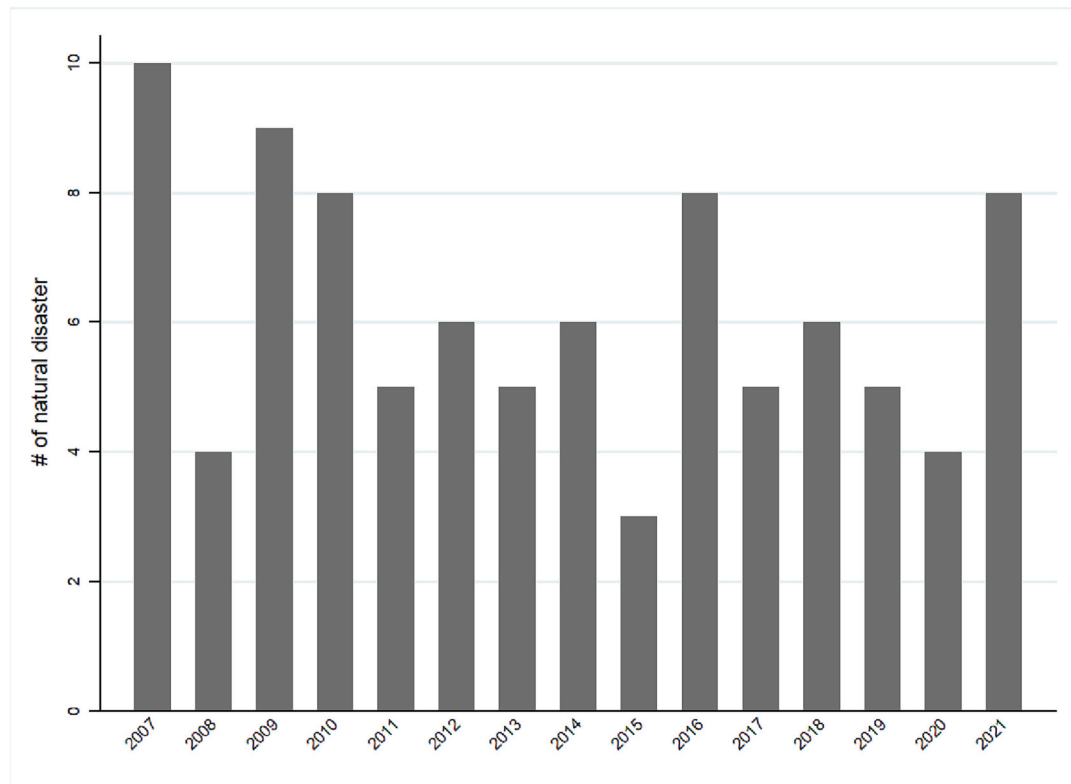


Fig. 1. Distribution of natural disasters by year.

in event windows $[0; +10]$ whereas the response of the CDS market is half in the following event window, around 0.18% and it reaches not more than 0.14% in the event windows $[0; +3]$ and $[0; +1]$. The greater reaction of the CDS market recorded in the event window $[0; +10]$ implies that the investors gradually adapt their decision to cover the default of the country that has been impacted by natural disasters. The most significant impact is especially in Eastern and Southern European countries. This can be explained by the fact that investors have started to price the default risk of these countries more highly for two reasons. First, Southern European countries (such as Italy, Greece, Portugal and Spain) experienced a series of economic-financial difficulties during this period, which led to the sovereign debt crisis. In fact, high levels of public debt, and difficulties in accessing the financial markets (e.g., Greece in 2010–2012), undermine the government's ability to make timely use of funds to finance recovery. As [Brei, Mohan, and Strobl \(2019\)](#) point out “the net economic impact of a disaster is determined by the ability of a country to mobilize re-investment finance”. Hence, the country's ability to mobilise financing plays a crucial role in mitigating the financial-economic impact of an extreme event in preventing

contagion effects between countries. In fact, according to Eurostat statistics,⁷ these countries have the highest ratios of public debt to GDP at the end of 2021, with values of 189.3% (Greece), 152.6% (Italy), 127.0% (Portugal), and 117.7% (Spain), respectively.

High public debt and low economic prospects can trigger the perception among investors that states will not be able to repay their debt ([Castro, 2013](#); [Fontana & Scheicher, 2016](#)).

Second, the specificity of the extreme events that affect these regions. Events such as earthquakes have an impact of significant duration and economic magnitude. Therefore, such natural disasters trigger substantial concerns about public debt sustainability.

Our results document the existence of a dangerous vicious circle between public debt sustainability and the impact of natural disasters. Also, the results divided by geographical regions underline that the effects of natural disasters behave dissimilarly in each geographical region. These different impacts may increase financial inequalities within Europe (*Hypothesis 2*). The higher cost of financing for governments, and thus less room for manoeuvre for public finances, can increase economic and financial heterogeneity between countries ([Cappelli, Costantini, &](#)

⁷ Please see: <https://ec.europa.eu/eurostat/documents/2995521/14497748/2-22042022-AP-EN.pdf>

Table 2

Event study: reaction of sovereign CDS spreads to a natural disaster.

Event window (days)	[0,+15]	[0, +10]	[0, +5]	[0, +3]	[0,+2]	[0,+1]
Panel A: Full sample						
CAR (%)	0.4332	0.3817	0.1825	0.1828	0.1346	0.1126
Bootstrap (p-value)	(0.3242)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0006)***
Wilcoxon test (p-value)	(0.5357)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***
Panel B: Eastern Europe						
CAR (%)	0.7230	0.6402	0.2306	0.1085	0.0437	0.01642
Bootstrap (p-value)	(0.6321)	(0.0000)***	(0.0000)***	(0.0003)***	(0.0019)***	(0.0015)***
Wilcoxon test (p-value)	(0.5732)	(0.0000)***	(0.0000)***	(0.0271)**	(0.0520)*	(0.0940)*
Panel C: Northern Europe						
CAR (%)	0.0440	0.0520	0.0110	0.0535	0.0412	−0.0048
Bootstrap (p-value)	(0.6321)	(0.0000)***	(0.0005)***	(0.6367)	(0.6563)	(0.6875)
Wilcoxon test (p-value)	(0.3421)	(0.0000)***	(0.0017)***	(0.2507)	(0.3346)	(0.1633)
Panel D: Southern Europe						
CAR (%)	0.5166	0.4448	0.2488	0.2928	0.2648	0.2882
Bootstrap (p-value)	(0.5219)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***
Wilcoxon test (p-value)	(0.8547)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***
Panel E: Western Europe						
CAR (%)	0.1450	0.1384	0.0694	0.0919	0.0253	0.0535
Bootstrap (p-value)	(0.5211)	(0.0730)*	(0.0000)***	(0.3071)	(0.0000)***	(0.0000)***
Wilcoxon test (p-value)	(0.8584)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0592)*	(0.0000)***

The table reports the CARs (in %) in response to a natural disaster. Panel A reports the reaction of CDS spreads to natural disasters for the full sample. Panel B reports the reaction of CDS spreads to natural disasters in Eastern Europe. Panel C reports the reaction of CDS spreads to natural disasters in Northern Europe. Panel D and E report the reaction of CDS spreads to natural disasters in Southern and Western Europe, respectively.

Significance is tested using two non-parametric tests: bootstrapped standard errors and Wilcoxon. We report the *p*-value of the two tests.

***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Consoli, 2021).

To further investigate the impact of natural disasters on sovereign CDS spreads, we run the event study for each subgroup identified in our sample. To avoid biased results, we exclude from the analysis the extra-terrestrial event due to the insufficient number of observations. The results of the event study by subgroups are reported in Table 3. The table indicates that geophysical and weather disasters have a strong positive effect (increased credit risk) both in the very short term and at 10 days. This result can be explained by the fact that the physical damage caused by geophysical disasters is much larger than in other disasters (as in Klomp, 2015). According to the EM-DAT dataset, the estimated damage for these types of events is more than 1 million US \$, i.e., 5.86% larger than the average. On the other hand, the results show that meteorological and hydrological events have weaker effects on CDS dynamics. These results are perfectly in line with the work of Pagnottoni et al. (2022), who find the same stock returns dynamics in international capital markets and confirm Hypothesis 3.

5.2. Contagion effect

In addition to the previous analysis, we extend the study, verifying the presence of the contagion effect on the sovereign CDS market of countries not directly involved in a natural disaster. To measure the contagion effect and the consequent propagation effect, we carry out a second event study in which the event is a natural disaster that occurred in another country.

Table 4 reports the results of the contagion effect confirming our hypothesis 4 of a *cross-border propagation effect*. Natural disasters, in general, are not local events but spread to other countries.

We can observe that in the very short term, investors' reaction to natural disasters is the same for each region. In fact, we find that in the interval [0; +1] and [0; +2], the event positively impacts the CDS, i.e., increased credit risk. Hence, these findings highlight the contagion effect due to natural disasters. Around [0; +3] and [0; +5], we notice an opposite effect, i.e., a reduction in CDS. This pattern is in line with the efficient market hypothesis (Fama, Fisher, Jensen, & Roll, 1969), i.e., securities (in our case, CDS) adjust quickly to the arrival of new information. Therefore, once the natural disaster has occurred, investors close their positions (sell CDS) in countries that are not affected by

natural disasters, so the contagion effect is reduced. Interesting is the dynamics of contagion 10 days after the event. For a longer period, the investors try to adequate their investment decisions. Specifically, the investors start to acquire the protection of the countries not directly affected by the natural disasters for fear of possible repercussions linked to the natural disaster that hits the other country, such as reductions in imports/exports or, in the worst cases, disruption of import/export (as experienced during the pandemic period), increases of NPLs, and losses of credit exposure value.

The impact of a natural disaster on the financial markets can be significant with the strongest effects typically observed within the first 10 trading days following the event. However, the duration and magnitude of these effects can vary depending on the region in which the countries are located. The empirical results have shown that once the initial uncertainty subsides, the need for protection against default in countries not directly affected by natural disasters is negligible in Southern, Eastern and Western regions, but remains positive and statistically significant in Northern Europe. Investors may behave differently because of several reasons. First, Northern Europe has strong trade relationships with countries located in Southern Europe such as Italy, Spain, and Greece. Since the imports from Southern to Northern Europe are basically based on agricultural products, the occurrence of a natural disaster may lead to fears about the possibility to import these products. Second, the exchange rate between the euro and the Norwegian krone may also impact the trade between Norway and Southern Europe. After a natural disaster, the euro may depreciate relative to the krone, it may become more expensive for Southern European companies to import products from Norway, and vice versa (Hale, 2022). This may lead to changes in the pattern of trade between these regions. Third, government interventions to safeguard against natural disasters may have an indirect effect, i.e., knowing that the government will demand higher taxes from citizens to cover such disasters, consumers/investors already reduce consumption at time *t* (today). Norway's CDS spread is the one with the lowest deviation standard, so it is the least volatile (Table A.2). This means that the higher financial domestic stability can be distorted by uncertainty about the revolution/management of a natural disaster in other countries. The contagion effect is therefore more persistent than the internal shock. Leading countries in contagion effect are the countries in Southern Europe probably because they are leading countries in

Table 3

Event study: reaction of sovereign CDS spreads to a natural disaster by subgroups.

Event window (days)	[0, +15]	[0, +10]	[0, +5]	[0, +3]	[0,+2]	[0,+1]
Panel A: Climatological						
CAR (%)	0.6760	0.6164	0.2885	0.2452	0.1827	0.1686
Bootstrap (p-value)	(0.1017)	(0.0117)**	(0.0010)***	(0.0215)**	(0.0107)**	(0.0215)**
Wilcoxon test (p-value)	(0.1604)	(0.0069)***	(0.0030)***	(0.0064)***	(0.0054)***	(0.0079)***
Panel B: Geophysical						
CAR (%)	0.6544	0.5628	0.2621	0.2965	0.2563	0.2770
Bootstrap (p-value)	(0.1250)	(0.0625)*	(0.0391)**	(0.0695)*	(0.0751)*	(0.0624)*
Wilcoxon test (p-value)	(0.2523)	(0.0252)**	(0.0252)**	(0.0583)*	(0.0389)**	(0.0583)*
Panel C: Hydrological						
CAR (%)	0.4755	0.4381	0.2198	0.2069	0.1589	0.1395
Bootstrap (p-value)	(0.0803)*	(0.0001)***	(0.0000)***	(0.0006)***	(0.0000)***	(0.0195)**
Wilcoxon test (p-value)	(0.1631)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0028)***
Panel D: Meteorological						
CAR (%)	0.2521	0.2402	0.0950	0.1122	0.0611	0.0247
Bootstrap (p-value)	(0.0706)*	(0.0801)*	(0.0046)***	(0.1628)	(0.0201)**	(0.3771)
Wilcoxon test (p-value)	(0.1004)	(0.0012)***	(0.0107)**	(0.0112)**	(0.0881)*	(0.4202)

The table reports the CARs (in %) in response to a natural disaster. Panel A reports the reaction of CDS spreads to climatological events. Panel B reports the reaction of CDS spreads to geophysical events. Panel C and D report the reaction of CDS spreads to hydrological and meteorological events.

Significance is tested using two non-parametric tests: bootstrapped standard errors and Wilcoxon. We report the *p*-value of the two tests.

***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 4

Event study: Contagion effect of a natural disaster.

Event window (days)	[0,+15]	[0, +10]	[0, +5]	[0, +3]	[0,+2]	[0,+1]
Panel A: Full sample						
CAR (%)	0.3526	0.2806	−0.1273	−0.0853	0.0087	0.0302
Bootstrap (p-value)	(0.1223)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0004)***	(0.0000)***
Wilcoxon test (p-value)	(0.2141)	(0.0000)***	(0.0000)***	(0.0000)***	(0.5470)	(0.0000)***
Panel B: Eastern Europe						
CAR (%)	0.4130	0.3599	−0.3216	−0.2721	0.0994	0.0981
Bootstrap (p-value)	(0.6352)	(0.0000)***	(0.0000)**	(0.0000)***	(0.0000)***	(0.0000)***
Wilcoxon test (p-value)	(0.3521)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***
Panel C: Northern Europe						
CAR (%)	0.9113	0.6842	0.1331	−0.0014	0.0964	0.0698
Bootstrap (p-value)	(0.5252)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***
Wilcoxon test (p-value)	(0.5747)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0108)**
Panel D: Southern Europe						
CAR (%)	−0.3257	−0.1051	−0.1367	−0.0513	0.1013	0.0297
Bootstrap (p-value)	(0.4241)	(0.0000)***	(0.0000)***	(0.2051)	(0.0000)***	(0.0000)***
Wilcoxon test (p-value)	(0.8544)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***
Panel E: Western Europe						
CAR (%)	0.2326	0.1020	−0.1476	−0.0535	0.0202	0.0304
Bootstrap (p-value)	(0.0991)*	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***
Wilcoxon test (p-value)	(0.0872)*	(0.0000)***	(0.0000)***	(0.8729)	(0.0000)***	(0.3602)

The table reports the CARs (in %) in response to a natural disaster. Panel A reports the reaction of CDS spreads to natural disasters for the full sample. Panel B reports the reaction of CDS spreads to natural disasters in Eastern Europe. Panel C reports the reaction of CDS spreads to natural disasters in Northern Europe. Panel D and E report the reaction of CDS spreads to natural disasters in Southern and Western Europe, respectively.

Significance is tested using two non-parametric tests: bootstrapped standard errors and Wilcoxon. We report the *p*-value of the two tests.

***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

natural disasters (more events in these countries). Moreover, Southern Europe are the countries that have had several debt solvency problems in recent years (e.g., Greece, Italy, and Spain). According to the literature (Bratis, Laopodis, & Kouretas, 2018; Le, Dickinson, & Le, 2022; Shambaugh, Reis, & Rey, 2012) we can interpret these countries as risk emitters (negative sign), towards other countries (positive sign) from the range [0,+10] days following the natural disaster. This may justify the different reactions of the sovereign CDS spread in Southern and Northern Europe.

6. Further analysis: Case studies

To further investigate the reaction of the sovereign CDS spreads to the occurrence of a natural disaster and the inequality generated by the occurrence of a natural disaster, we focus on some particular countries. Specifically, we run separately the event study analysis for those countries that have suffered, during the period 2007–2021, the highest

number of natural disasters. We focus on Germany, Italy and Russia which have suffered 12, 22 and 15 events during the sample periods, respectively. Table 5 reports the results of the case studies. Although the occurrence of a natural disaster poses important questions on the sustainability of debt in Germany, Italy and Russia, the impact changes in relation to the considered country. The investors after the occurrence of a natural disaster start to buy protection against the default of the country directly affected by the natural disasters. However, the investors heavily purchase protection against the country's default for those countries in weaker financial conditions.

On the day of the occurrence of a natural disaster in Germany, investors close their positions (sell CDS). After two trading days in which the local authorities count for the damage of a natural disaster, the investors become more fearful and try to cover the risk deriving from the occurrence of a natural disaster by buying protection (buy CDS).

Looking at the effect that a natural disaster may have on debt sustainability in Italy, we observe the opposite direction of the investors on

Table 5

Case studies: reaction of sovereign CDS spreads to a natural disaster in Germany, Italy and Russia.

Event window (days)	[0, +15]	[0, +10]	[0, +5]	[0, +3]	[0, +2]	[0, +1]
Panel A: Germany						
CAR (%)	0.5334	0.4169	0.1023	0.2519	0.0978	−0.0644
Bootstrap (p-value)	(0.0857)*	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***
Wilcoxon test (p-value)	(0.1042)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***
Panel B: Italy						
CAR (%)	0.7722	0.6999	0.3218	0.4605	0.4120	0.4710
Bootstrap (p-value)	(0.0522)*	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***
Wilcoxon test (p-value)	(0.0689)*	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***
Panel C: Russia						
CAR (%)	1.0892	0.9299	0.4137	0.2582	0.1408	0.0635
Bootstrap (p-value)	(0.0587)*	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***
Wilcoxon test (p-value)	(0.0502)*	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***

The table reports the CARs (in %) in response to a natural disaster. Panel A reports the reaction of CDS spreads to natural disasters in Germany. Panel B and C report the reaction of CDS spreads to natural disasters in Italy and Russia, respectively.

Significance is tested using two non-parametric tests: bootstrapped standard errors and Wilcoxon. We report the *p*-value of the two tests.

***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

the first trading day after the occurrence of a natural disaster. The fears about the damage caused by the event push investors to ask for protection against the default of the country, and this is translated into an increase in sovereign CDS spread of more than 0.40%. Finally, the reaction of the sovereign CDS market on the first trading day after the occurrence of a natural disaster in Russia is close to zero implying that the investors do not care about the possible repercussions of the event in debt sustainability. However, it becomes gradually higher until, in the 15 trading days after the occurrence of the natural disaster, the increase of the sovereign CDS spreads reaches 1.09% (the highest value if compared to Italy and Germany).

These findings underline how natural disasters impact debt sustainability and how the financial fragility of countries makes them more vulnerable to the effects of natural disasters. Moreover, the table shows that Italy's natural disasters provoke a greater impact on CDS spread in the short term than Germany and Russia. The heterogeneity of the effects of natural disasters justifies this result. As shown in Table A1 (Appendix), Italy is the country most affected by geophysical disasters. Such extreme natural events cause much higher real and management costs than those caused by other disasters. Just think of the collapse of a house. This event will cause an increased risk in the real estate sector and, thus, to homeowners. This effect branches out to the banking sector (credit effect) and thus to the country's risk (diabolical loop).

6.1. Sovereign CDS response to natural disasters: The mitigation role of geographical proximity

To further analyse the impact of natural disasters on credit risk contagion, we use the spatial econometric analysis, i.e., the dynamic spatial autoregressive (dySAR) model. This specific econometric method allows us to determine the direct/indirect and short/long effect of natural disasters. The main feature of this branch of econometrics frameworks is that it includes the “closeness” weighted matrix between observations (in our case, between countries) in the estimation of the model, which determines the structure of dependence among observations (LeSage & Pace, 2009). Thus, it helps us to understand whether proximity can be an important variable for the dynamics of credit risk. In our case, we used the geographical proximity matrix as in Dell’Erba, Baldacci, and Poghosyan (2013). Applying this model structure, we address the question of how a country's credit risk (CDS spread) also depends on the impact of a natural disaster on other countries. This type of model, therefore, allows us to investigate and quantify the presence of

spillover effects.⁸

Table 6 shows the results of the SAR model. ρ is the spatial spillover coefficient and it is statistically significant at 1%. This result shows the existence of a significant spillover effect between countries, i.e., that contagion is present. Natural disasters positively affect the CDS spread dynamic, i.e., the extreme event increases the credit risk. As we can see, the estimation remains robust even after macroeconomic control factors in the regression models.

In Table 7 we report the estimations of the spatial effect, i.e., the direct and indirect in the short and long-run term, respectively. The direct effect shows the effect of the natural disaster directly on the affected country, while the indirect effect reveals the vulnerability of countries to the natural disasters of other countries. Total effects are the sum of direct and indirect effects. Recall that since the data are daily, the short-run effect is the impact of the natural disaster at time *t* on the CDS at time *t*. The long-run effect captures the natural disaster at time *t-1* on CDS at time *t*.

The findings suggest that a natural disaster in one country has a

Table 6

Dynamic spatial autoregressive (SAR) model estimation.

	(1)	(2)
ρ	0.393*** (0.024)	0.354*** (0.024)
ΔCDS_{t-1}	−0.285 (0.018)	−0.0304* (0.018)
Natural disaster	0.0673* (0.041)	0.0672* (0.040)
Control variables	NO	YES
Observations	64,804	64,804
R-squared	0.10	0.30
Number of countries	17	17
Country FE	YES	YES

The table reports the results of DySAR model. Standard-errors are reported in parentheses. Model (1) reports the baseline model without any control variables, while model (2) includes the other determinants to reduce the omitted factors. The list of control variables is calculated as the return for the VDAX, the change on 3-month Euribor, and the difference between the three-month Euribor and the overnight rate EONIA (Caporin, Pelizzon, Ravazzolo, & Rigobon, 2018).

***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

⁸ For the sake of brevity, we do not report the methodological aspects of dySAR model. However, they are available on request. Please see LeSage (2015) for the econometrics derivation of the model.

Table 7
Spillover effect impact.

Variable	Short-run Direct	Short-run Indirect	Long-run Direct	Long-run Indirect
Natural disaster	0.066*	0.035*	0.006*	0.003

The table reports the estimations of the direct and indirect in the short and long-run term, respectively.

***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

direct impact on itself and on other countries in the short term. On the other hand, in the long run term, natural disaster affects only the country hit by natural extreme. Hence, these results are perfectly in line with the event study analysis above.

7. Robustness

Since there are events in Europe that may have caused a distortion in the reaction of the CDS market to the occurrence of a natural disaster, the results are checked by running several tests.

First, we isolate the effect of the occurrence of a natural disaster from other possible events that have occurred in the same period. The sample period includes the period of the European sovereign debt crisis and some countries have suffered important problems in terms of debt sustainability that may have distorted the response of the sovereign CDS market to the occurrence of a natural disaster. Specifically, we consider the possible distortion effect of the introduction of the Troika⁹ on the response of the sovereign CDS market to the occurrence of a natural disaster, we check our results by removing Greece, Ireland and Portugal from our analysis. We re-run the event study following the methodology explained above in case of the full sample and Northern and Southern Europe, geographical areas in which Greece, Ireland and Portugal are located. Therefore, we exclude 5 natural disasters (3 occurred in Greece and 1 in Ireland and Portugal) of which 3 are climatological events and 2 are hydrological events. The results of the full sample and divided by geographical area, reported in Table 6, confirm the previous findings: *i*) the occurrence of a natural disaster undermines the sustainability of the debt by increasing the sovereign CDS spreads; *ii*) the occurrence of a natural disaster increases the inequality between the countries by impacting more the sustainability of debt in countries presenting weaker financial conditions and *iii*) the effect of a natural disaster disappear after the 10 trading days after the occurrence of a natural disaster.

The results divided by subgroup are reported in Table 8. This robustness test confirms our hypothesis. The reaction of the sovereign CDS spreads changes in relation to the different natural disasters. Although the reaction of the sovereign CDS spreads is positive and significant for all events, the size of the effect is greater in the case of climatological events. The sustainability of the debt becomes more untenable in the case of climatological events.

The results of the contagion effect are reported in Table 9. We confirm the previous findings: there is a contagion effect in European countries, and it holds in the first two trading days after the occurrence of a natural disaster. The uncertainty deriving from a natural disaster propagates to other countries not directly affected by the events. The investors adequate their investment decisions after the uncertainty of the first days by acquiring protection against the default of countries not directly affected by natural disasters in a longer time. (See Table 10.)

As a further robustness check, we delete the periods of the Global

Financial Crisis (GFC) and the EU Sovereign Debt crisis because of the high volatility of this period that could have altered the response of the sovereign CDS spreads to the occurrence of a natural disaster. The results, qualitatively similar to the previous, confirm the findings. The GFC and the EU sovereign Debt crisis have modified the magnitude of the effect, but they do not change the reaction of the sovereign CDS spreads to the occurrence of a natural disaster.¹⁰

8. Conclusion

Natural disasters regularly strike Europe. Fig. 1 shows the dynamics of natural disasters from 2007 to 2021. As can be seen, Europe is periodically affected by natural disasters. According to the European Environment Agency,¹¹ the total economic losses caused by natural hazards in European member states between 1980 and 2020 amounted to EUR 487 billion, or EUR 11.9 billion per year. Hence, natural disasters can put significant pressure on the public finances of member states, thus affecting the sustainability of public debt (Klomp, 2015). Moreover, in an increasingly interconnected world, extreme events such as natural disasters can also create economic repercussions for countries and financial systems in geographical areas not directly affected. In our work, we highlight how natural disasters affect not only one country's creditworthiness but also others' credit risk. Indeed, natural disasters cause disruptions in economic activity, which directly affects the credit risk of businesses and households. For example, the destruction caused by natural disasters may prevent borrowers from repaying their debts. This effect translates into lower bank solvency. Bank instability can undermine the stability of governments, given the "diabolical loop" channel (Brunnermeier et al., 2011; González-Velasco, García-López, & González-Fernández, 2022; Shambaugh et al., 2012). As the literature points out, this dangerous relationship can undermine the strength of the entire European financial system.

Overall, we find that: *i*) the reaction of the sovereign CDS market is positive, implying that the occurrence of a natural disaster increases the country's risk; *ii*) the response of the sovereign CDS market differs from region to region; *iii*) the contagion effect is present. The advent of a natural disaster can increase inequality between the regions due to the higher cost of credit for sovereigns and the reduced scope for manoeuvring of public finances.

Our empirical results indicate that catastrophes affect the resilience of financial stability through the size effect rather than the frequency effect. We can observe that although geological and climatological disasters occur much less frequently than meteorological and hydrological disasters (Table A.1), they have a more significant negative effect on debt sustainability. Furthermore, the results show that Southern and Eastern European countries are more exposed to credit default risk by natural disasters. This is explained by the fact that: *i*) these countries are more affected by geological (earthquake) and climatological (wildfire and drought) disasters, and *ii*) they are the countries that have had the most significant economic-financial difficulties in recent years. In fact, the financial fragility of these countries makes them more vulnerable to the effects of natural disasters, as they are unable in a timely manner (given their high levels of public debt) to mobilise funding for reinvestment following extreme events.

Based on our analysis, our findings suggest that while the impact of a natural disaster increases individual country risk, it contributes to the financial instability of the European system. Therefore, in addition to establishing individual country-specific policies, supervisors should examine the interaction of climate risk at the global level. A risk-sharing approach would be desirable. In fact, according to the World Bank

⁹ Troika was an ad hoc authority created by the European Commission, the European Central Bank and the International Monetary Fund in the aftermath of the European sovereign debt crisis with the aim to manage the "default" of Cyprus, Greece, Ireland and Portugal.

¹⁰ For the sake of brevity, the Tables showing the results of the event study run by excluding the GFC and the EU sovereign Debt crisis period are reported in the supplementary materials.

¹¹ <https://www.eea.europa.eu/ims/economic-losses-from-climate-related>

Table 8

Robustness event study: reaction of sovereign CDS spreads to a natural disaster.

Event window (days)	[0, +15]	[0, +10]	[0, +5]	[0, +3]	[0,+2]	[0,+1]
Panel A: Full sample						
CAR (%)	0.4580	0.4034	0.1912	0.1921	0.1414	0.1191
Bootstrap (p-value)	(0.2212)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0008)***
Wilcoxon test (p-value)	(0.8658)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***
Panel B: Northern Europe						
CAR (%)	0.0521	0.0396	0.0012	0.0004	0.0017	−0.0030
Bootstrap (p-value)	(0.5211)	(0.0010)***	(0.0313)**	(0.1250)	(0.2500)	(0.5000)
Wilcoxon test (p-value)	(0.3732)	(0.0009)***	(0.0143)**	(0.1455)	(0.0833)*	(0.1573)
Panel C: Southern Europe						
CAR (%)	0.5722	0.4936	0.2717	0.3246	0.2937	0.3198
Bootstrap (p-value)	(0.2141)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***
Wilcoxon test (p-value)	(0.7484)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***

The table reports the CARs (in %) in response to a natural disaster. Panel A reports the reaction of CDS spreads to natural disasters for the full sample. Panel B and C the reaction of CDS spreads to natural disasters in Northern and Southern Europe, respectively.

Significance is tested using two non-parametric tests: bootstrapped standard errors and Wilcoxon. We report the *p*-value of the two tests.

***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 9

Robustness event study: reaction of sovereign CDS spreads to a natural disaster by subgroups.

Event window (days)	[0, +15]	[0, +10]	[0, +5]	[0, +3]	[0,+2]	[0,+1]
Panel A: Climatological						
CAR (%)	0.9566	0.8336	0.3743	0.3457	0.2576	0.2386
Bootstrap (p-value)	(0.1562)	(0.0152)**	(0.0146)**	(0.0156)**	(0.0127)**	(0.0115)**
Wilcoxon test (p-value)	(0.3173)	(0.0156)**	(0.0172)**	(0.0124)**	(0.0164)**	(0.0179)**
Panel B: Hydrological						
CAR (%)	0.4985	0.4329	0.2222	0.2134	0.1648	0.1466
Bootstrap (p-value)	(0.9242)	(0.0000)***	(0.0000)***	(0.0022)***	(0.0000)***	(0.0166)**
Wilcoxon test (p-value)	(0.7442)	(0.0007)***	(0.0000)***	(0.0001)***	(0.0000)***	(0.0031)***

The table reports the CARs (in %) in response to a natural disaster. Panels A and B report the reaction of CDS spreads to climatological and hydrological events.

Significance is tested using two non-parametric tests: bootstrapped standard errors and Wilcoxon. We report the *p*-value of the two tests.

***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 10

Robustness event study: Contagion effect of a natural disaster.

Event window (days)	[0, +15]	[0, +10]	[0, +5]	[0, +3]	[0,+2]	[0,+1]
Panel A: Full sample						
CAR (%)	0.3036	0.1029	−0.1985	−0.2404	0.0819	0.0051
Bootstrap (p-value)	(0.3621)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0004)***
Wilcoxon test (p-value)	(0.6363)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.2641)
Panel B: Eastern Europe						
CAR (%)	0.4988	0.2347	−0.3484	−0.3100	0.1039	0.0252
Bootstrap (p-value)	(0.2131)	(0.0000)***	(0.0000)**	(0.0000)***	(0.0000)***	(0.0000)***
Wilcoxon test (p-value)	(0.4141)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0012)***
Panel C: Northern Europe						
CAR (%)	0.4193	0.3118	0.0129	−0.1729	0.0018	0.0826
Bootstrap (p-value)	(0.6362)	(0.0000)***	(0.0000)***	(0.0000)***	(0.1781)	(0.5158)
Wilcoxon test (p-value)	(0.2119)	(0.0000)***	(0.0000)***	(0.0000)***	(0.2615)	(0.1810)
Panel D: Southern Europe						
CAR (%)	−0.0412	−0.2758	−0.2019	−0.1927	0.1485	0.0162
Bootstrap (p-value)	(0.3621)	(0.0000)***	(0.0000)***	(0.2051)	(0.0000)***	(0.0000)***
Wilcoxon test (p-value)	(0.5625)	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0810)*
Panel E: Western Europe						
CAR (%)	0.0309	0.0607	−0.2132	−0.2840	0.1136	0.0552
Bootstrap (p-value)	(0.0743)*	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***
Wilcoxon test (p-value)	(0.0952)*	(0.0000)***	(0.0000)***	(0.8729)	(0.0000)***	(0.0000)***

The table reports the CARs (in %) in response to a natural disaster. Panel A reports the reaction of CDS spreads to natural disasters for the full sample. Panel B reports the reaction of CDS spreads to natural disasters in Eastern Europe. Panel C reports the reaction of CDS spreads to natural disasters in Northern Europe. Panel D and E report the reaction of CDS spreads to natural disasters in Southern and Western Europe, respectively.

Significance is tested using two non-parametric tests: bootstrapped standard errors and Wilcoxon. We report the *p*-value of the two tests.

***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

(2021) report, European governments finance an average of around EUR 16 billion in disaster costs per year. However, when access to financing is not available, the impact of natural disasters can be very high. Therefore, efficient and cohesive disaster risk financing strategies would help reduce risks and strengthen financial resilience.

Future research can investigate the reason for the contagion effect. We have the direction and the size of the contagion, but it will be useful to investigate, in future research, whether the motivation of the contagion can be linked to financial and economic factors such as bank exposure or import/export policies. This evolution would be useful for

regulators and policymakers to adopt ad hoc policies useful to avoid the spread of the crisis from country to country.

Data availability

Data will be made available on request.

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Appendix

Table A1

Distribution of natural disasters by countries.

Country	# of natural disaster					
	Climatological	Extra-terrestrial	Geophysical	Hydrological	Meteorological	Total
Austria	–	–	–	1	3	4
Belgium	–	–	–	2	2	4
Croatia	1	–	1	1	1	3
Czech Republic	–	–	–	–	1	1
France	–	–	–	3	3	6
Germany	–	–	–	4	8	12
Greece	2	–	–	1	–	3
Ireland	–	–	–	1	–	1
Italy	3	–	4	11	4	22
Netherlands	–	–	–	–	3	3
Norway	–	–	–	1	–	1
Poland	–	–	–	2	2	4
Portugal	1	–	–	–	–	1
Romania	–	–	–	1	–	1
Russia	4	1	1	8	1	15
Slovenia	–	–	–	1	2	3
Spain	–	–	1	5	2	8
Total	10	1	7	42	32	92

Table A2

Summary statics of sovereign CDS spreads divided by country.

Country	CDS spreads			
	Means	Sd	Min	Max
Austria	28.73	31.62	5.01	159.23
Belgium	46.13	55.21	5.00	341.08
Croatia	210.01	117.75	45.67	592.50
Czech Republic	60.27	41.47	27.46	350.00
France	24.38	17.29	5.58	94.00
Germany	16.68	15.36	4.78	92.50
Greece	5580.63	6864.58	26.90	14,911.74
Ireland	139.09	201.01	5.11	1191.16
Italy	120.75	89.71	16.38	498.66
Netherlands	31.35	28.36	6.25	133.84
Norway	16.71	9.10	6.95	62.00
Poland	91.09	59.41	34.43	421.00
Portugal	216.34	276.79	15.58	1521.45
Romania	181.59	126.51	60.21	776.20
Russia	460.07	1767.12	51.09	14,981.09
Slovenia	114.02	90.01	8.00	448.67
Spain	98.31	96.98	10.44	492.07
Total	321.65	1736.78	4.78	14,981.09

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.irfa.2023.102578>.

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