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NATURAL CATASTROPHES AND BANK LENDING: THE CASE OF FLOOD RISK IN ITALY

by Ivan Faiella* and Filippo Natoli*

Abstract

We investigate the relationship between bank lending and catastrophe risk by analyzing the exposure of banks to Italian firms located in areas at risk of flooding. By matching a new map of flood risk areas with proprietary data on bank loans at municipal level we find that, on controlling for sectoral- and province-level fixed effects, lending to non-financial firms is negatively correlated with their flood risk exposure. A province-level analysis, which also allows us to control for bank- and firm-specific factors, confirms this finding when the borrowers are small and medium-sized enterprises. This investigation gives an initial insight into the relationship between the risk of natural catastrophes - exacerbated by climate change - and lending decisions.

JEL Classification: G21, P48, Q54.
Keywords: catastrophe risk, climate change, rare disasters, bank lending, flooding, Italy.

Contents

* Bank of Italy, Directorate General for Economics, Statistics and Research.

1 Introduction*

Climate change is causing a structural transformation of the natural environment. One important effect of this ongoing process is the increasing frequency and intensity of adverse natural events, which poses material risks for the economy. Natural catastrophes are local phenomena but their consequences spread out over the economic system, just like other extreme, rare events. One relevant propagation mechanism is the credit channel: physical damages and business disruptions caused by natural events may affect the ability of borrowers to repay back loans, eventually forcing banks to fire sale assets and ration credit. The ability of banks to price and hedge this risk ex-ante is key to avoid unintended consequences on credit and asset prices.

We investigate the connection between catastrophe risk and bank lending by analyzing lending activity to Italian firms located in areas at risk of flood. Flood risk is one of the most relevant sources of catastrophe risk in Italy and, at the same time, is highly heterogeneously distributed over the Italian territory. We adopt the mapping of flood risk realized in 2015 by the Italian Institute for Environmental Protection and Research (ISPRA) and construct an indicator at the municipal level as the share of firms located in high-risk flood areas within each municipality. The analysis is conducted in two steps: first, we match data on flood risk with proprietary data on bank loans – from the Italian Central Credit Register – by geographic location of credit; then, using municipal-level ag-gregations, we correlate the level of flood risk with the amount of credit granted to firms by the banking sector. Provided that firms may operate in different areas (possibly more risky) than those in which they are legally resident, we impute loans to the municipality of the lending bank branch, supposedly closer to the final use destination of credit.

Controlling for sectoral- and province-level fixed effects, we find that catastrophe risk have a negative effect on bank lending. As a robustness check, we repeat our regression using province-level data from a different proprietary dataset – compiled from the surveillance reports of banks to the Bank of Italy – which allows to distinguish between credit granted by big and small banks and received by big and small firms: results are confirmed in the case of loans granted to small and medium-sized enterprises. While there is no identification of demand and supply drivers of credit, our results may suggest that banks can discriminate borrowers by their catastrophe risk exposure but ration credit only to small companies, that are less able to diversify risk.

*We are indebted to Andrea Orame for providing us high quality municipal level data. We thank the ISPRA research team for useful clarifications on ISPRA data. We also thank Luigi Cannari and the participants in the 3rd Banking Research Network workshop of the Bank of Italy and the 30th Villa Mondragone International Economic Seminar for the useful comments and suggestions. The views expressed in this paper are those of the authors and do not necessarily reflect those of the Bank of Italy. All the remaining errors are ours. E-mail: ivan.faiella@bancaditalia.it, filippo.natoli@bancaditalia.it.

The relevance of these results seems not to depend on the lack of information on flood insurance penetration in the industry sector: indeed, survey data on catastrophe insurance collected for the first time in 2017 by the Bank of Italy show that insurance penetration is not even high for large firms,suggesting that the industry (and, by consequence, the banking sector) remains largely exposed to natural disasters.

Overall, our results suggest that credit availability may not be independent on one of the main sources of catastrophe risk, opening to new research on the topic. While the estimation is in reduced form and it is mainly used as a descriptive tool, results come from the analysis of the *entire population* of bank-firm relationships, not from those existing in limited areas, as in most papers on the topic; moreover, for the fact of being independent on the occurrence of catastrophic events, cross-section estimates can be replicated over time to track the lending behaviour in risky areas. Our method, that is based on publicly available information on the degree of flood risk by geographic areas, allows to give a first insight on the *ex-ante* perception of risk, without making inference from the ex-post be-havior of agents. As far as we know, this is the first study which proposes a classification of the entire stock of credit in one economy by climate-related riskiness of the borrower. Concerning Italy, this is the first economic study using a new, detailed territorial flood mapping, and one of the first dealing with catastrophe risk from the perspective of Italian banks.

2 Literature review

Many papers investigate the effects of natural catastrophes. Some of them focus on local socio-economic effects, as the direct economic and demographic damage (Cavallo et al., 2010) and the variation in growth rates in affected cities (Strobl, 2011), as well as on the risks and opportunities linked to the reconstruction (Vigdor, 2008); others look at macroeconomic implications in terms of short- and long-term growth (Cavallo et al., 2013; McDermott et al., 2014), of cross-country capital flows (Odell and Weidenmier, 2004), and of the different effects in advanced vs emerging economies (Noy, 2009). The reported results, while rich in terms of economic analysis, mainly come from the evidence on hurricanes and earthquakes, so they are not representative of the entire spectrum of hydrogeological events. Moreover, they mostly focus on the United States, and in particular on specific areas of that country that have historically suffered the most from those types of natural catastrophes.

From a theoretical point of view, unpredictable natural catastrophes can be analyzed in the same frameworks which embed large macroeconomic shocks, or rare disasters. Starting from the seminal work of Rietz (1988), the literature on rare disasters has emphasized the effects of a non-negligible probability of disasters on equilibrium asset prices (Barro, 2006; Barro and Ursúa, 2012; Gabaix, 2012; Gourio, 2012; Wachter, 2013). While theoretical models typically do not include the banking sector, the economic research is showing growing interest on the link between natural disasters and bank lending. Morse (2011) analyzes the role of payday lenders in mitigating financial distress caused by natural disasters; Cortés and Strahan (2017) investigate how banks alter their credit supply decisions in response to shocks to local credit demand stimulated by natural disasters; Garmaise and Moskowitz (2009) analyze the implications of earthquake risk on real estate financing. A literature review on the consequences of natural disasters on banks is reported in Klomp (2014).

Few papers before ours have specifically focused on floods. Looking at a number of flood events in the UK and to housing market developments in affected areas, Lamond et al. (2010) do not find broad-based evidence of a strong and persistent impact of floods on house prices; opposite evidence is instead reported in Belanger and Bourdeau-Brien (2017) who examine the effects of flood risk on property prices in the United Kingdom and find a significant "flood risk discount" for both waterfront properties and real estates that are located farther away within the same area. Koetter et al. (2016) exploit the 2013 Elbe flooding in Germany to assess how lending behaviour has changed after that event, finding that local banks with sound relationship with flooded firms lent more than big banks in the aftermath of the flood, mitigating the effects of the shocks on the industry sector. Our paper gives some insights on the risk perception of banks. Lending choices in risky provinces can be informative on banks' awareness of catastrophe risk or on their willingness to take it on. Provided that studies on property values and insurance markets hint on the underestimation of catastrophe risks by households and insurance companies, this might also be the case for the banking sector.[1]

The rest of the paper is organized as follows. Section 3 presents hydrogeological risk and describes the dataset. Section 4 explains the estimation strategy, comments on the results and discusses key issues. Section 5 concludes.

[1] Other evidence relates to insurance and reinsurance companies. Concerning insurance companies, a study by Lloyds (2014) note that most catastrophe models used by insurers and other agents still tend to rely on historical data without incorporating climate change trends explicitly; moreover, according to Standard and Poor's (2014), reinsurers do not believe that climate change is having a material impact on their current risk exposure.

3 Hydrogeological risk in Italy

In this Section we present evidence on hydrogeological risk in Italy. First, we characterize the main sources of risk in this country; then, we comment on the current level of flood risk borne by Italian firms, focusing on the geographic distribution of local business units over the Italian territory.

3.1 Historical perspective

Italy is particularly exposed to hydrogeological risk because of its geomorphological characteristics and the intense urbanization that followed the economic post-war boom. Table 1 reports aggregate statistics on floods and landslides between 1950 and 2011, divided in two subperiods (1950 – 2008, upper panel, and 2009 – 2011, middle panel). Over the entire sample, the relevance of the exposure to hydrogeological risk is witnessed by the average number of events per year (65) and the total population involved over the history (more than three million people); moreover, the economic damage is estimated to be at least 2.7 billion euro per year, according to Faiella (2013).

Floods have historically been less frequent than landslides; however, the number of casualties associated to flood events is estimated to be higher than that of landslides, particularly for the last two years of the sample.[2] Moreover, the frequency of floods is projected to increase significantly: climate simulations made with a hydrogeological model shows that flood frequency in Italy could almost double by 2050 and triple by 2080 (Alfieri et al., 2015). All in all, the evidence suggests that floods can be considered as the main source of hydrogeological risk for households and firms located over the Italian territory.

3.2 Local Business Units at risk of floods

In order to support national climate-related policies, Trigila et al. (2015) (the ISPRA report, henceforth) have created a database of the population (households, firms and cultural heritage sites) exposed to the risk of floods and landslides over the Italian territory. The database has been constructed in two steps: first, for each of the two types of natural events, land has been categorized in terms of riskiness using granular environmental data and information about the historical occurrence of each event; second, both land datasets have been matched with data on the geographic residence of households, firms and cul-

[2] In line with data on casualties, also damages related to past flood events are estimated to be higher than those related to landslides, according to Faiella (2013).

	N. of events	Involved Pop	N. of casualties	Events/year	Casualties/year	Casualties/event
1950-2008						
Landslides	2,204	177,376	4,103	37	70	1.86
Flooding	1,654	497,334	1,214	28	21	0.73
Total	3,858	674,71	5,317	65	90	1.38
2009-2011						
Landslides	133	4,7	38	44	13	0.29
Flooding	31	2,335,500	104	10	35	3.35
Total	164	2,340,200	142	55	47	0.87
1950-2011						
Landslides	2,337	182,076	4,141	38	67	1.77
Flooding	1,685	2,832,834	1,318	27	21	0.78
Total	**4,022**	**3,014,910**	**5,459**	**65**	**88**	**1.36**

Table 1: Hydrogeological events in Italy. total number of events, estimated population involved and total number of casualties: 1950-2011. Source: Faiella (2013).

tural heritage sites taken from the 2011 ISTAT census (the last one available), obtaining statistics of the population exposed to flood and landslide risk at different risk levels.[3]

Following the evidence reported in Section 3.1 and the unavailability of a joint flood-landslide risk mapping, we restrict our analysis to flood risk. Land categorization for flood risk is constructed using data collected from river basin authorities, municipalities, provinces, regions and other public authorities.[4] Land is categorized at low, medium, high or no risk of flood based on the estimated frequency of flood events over time: areas in which floods are estimated to occur once in 20–50 years are flagged as high-risk areas, while those in which floods are estimated to be less frequent (once in 100–200 years and once in more than 200 years) are labelled as medium- and low-risk areas, respectively. Areas at lower risk are farther from the river basins and damaged only in case of large floods: indeed, in the classification made in the ISPRA report, low-risk areas include medium-risk ones, and medium-risk areas include high-risk ones. Figure 3.1 shows

[3]For further details, on the ISTAT census, search *9th Censimento generale dell'industria e dei servizi e Censimento delle istituzioni non profit* at `www.istat.it`. ISTAT census of firms are conducted once every ten years.

[4]River basin authorities are public entities in charge of supervising the conservation and sustainable use of river resources, pursuing hydrogeological risk mitigation policies and contributing to structural and non-structural measures programming.

	# LBUs	LBUs at risk by risk level			share by risk level (%)			Value Added
		high	medium	low	high	medium	low	(% of tot VA)
Abruzzo	109,925	2,135	13,435	3,569	1.9	12.2	3.2	1.9
Basilicata	38,043	219	333	352	0.6	0.9	0.9	0.6
Calabria	117,904	3,924	4,900	6,749	3.3	4.2	5.7	1.9
Campania	362,502	6,010	15,098	17,788	1.7	4.2	4.9	6.2
Emilia Romagna	403,272	40,665	254,337	160,280	10.1	63.1	39.7	9.0
Friuli	95,940	2,573	7,505	9,817	2.7	7.8	10.2	2.2
Lazio	456,377	7,060	13,134	54,156	1.5	2.9	11.9	11.4
Liguria	140,737	25,114	37,376	47,570	17.8	26.6	33.8	2.9
Lombardia	888,054	18,867	28,578	97,879	2.1	3.2	11.0	22.1
Marche	142,657	836	7,101	3,629	0.6	5.0	2.5	2.5
Molise	23,254	126	444	541	0.5	1.9	2.3	0.4
Piemonte	369,062	7,835	18,843	58,112	2.1	5.1	15.7	7.6
Puglia	269,834	4,927	7,926	10,186	1.8	2.9	3.8	4.3
Sardegna	117,588	4,931	7,817	19,431	4.2	6.6	16.5	1.9
Sicilia	291,506	1,014	1,609	1,874	0.3	0.6	0.6	5.3
Toscana	358,984	23,281	105,605	257,770	6.5	29.4	71.8	6.8
Trentino	91,614	1,600	2,224	5,136	1.7	2.4	5.6	2.3
Umbria	75,262	2,682	5,750	9,187	3.6	7.6	12.2	1.3
Valle D'Aosta	12,876	573	1,245	5,209	4.5	9.7	40.5	0.3
Veneto	440,623	31,894	43,275	110,129	7.2	9.8	25.0	9.2
total	**4,806,014**	**186,266**	**576,535**	**879,364**	**3.9**	**12.0**	**18.3**	100

Table 2: Statistics on flood risk by Italian region. Column 1: total number of LBUs from the 2011 Census; columns 2 to 7: number of LBUs at risk and percentages by risk level (from the ISPRA report); column 8: regional share of national value added, computed from ISTAT data. Data on LBUs at risk for Marche are an underestimate of the number of firms at risk in that region.

the geographical distribution over the Italian territory of areas at low-risk (left picture), medium-risk (center picture) and high-risk (right picture), with grey lines indicating regions' borders. According to the maps, in 2014 10.6 percent of the Italian territory was exposed to flood risk, of which 4.0 percent to high-risk.

In this paper we focus on Italian firms, leaving households and cultural heritage sites for further analyses. Concerning firms, the ISTAT census reports detail of the Local Business Units (LBUs henceforth), defined as "economic units that perform arts and professions in industry, trade and services in favor of enterprises and households". In general, firm's activity can be organized in more than one LBU: in the census, ISTAT assigns the exact geographic location to each of them, irrespective of the legal residence of the company. This aspect is key in our investigation, because it allows for a correct quantification of the physical risk concentrated in each province. We extract province-level data from Table 5.24 of the ISPRA report and compute summary statistics. Table 2 shows the geographic distribution of LBUs at risk of flood by the 20 Italian regions: 18.3 percent of the total LBUs are exposed to flood risk, of which 3.9 per cent at high-risk. Looking at the regional breakdown, Emilia-Romagna, Veneto, Liguria, Tuscany and Sardinia have the highest concentration of LBUs at high-risk: these regions together produce almost a third

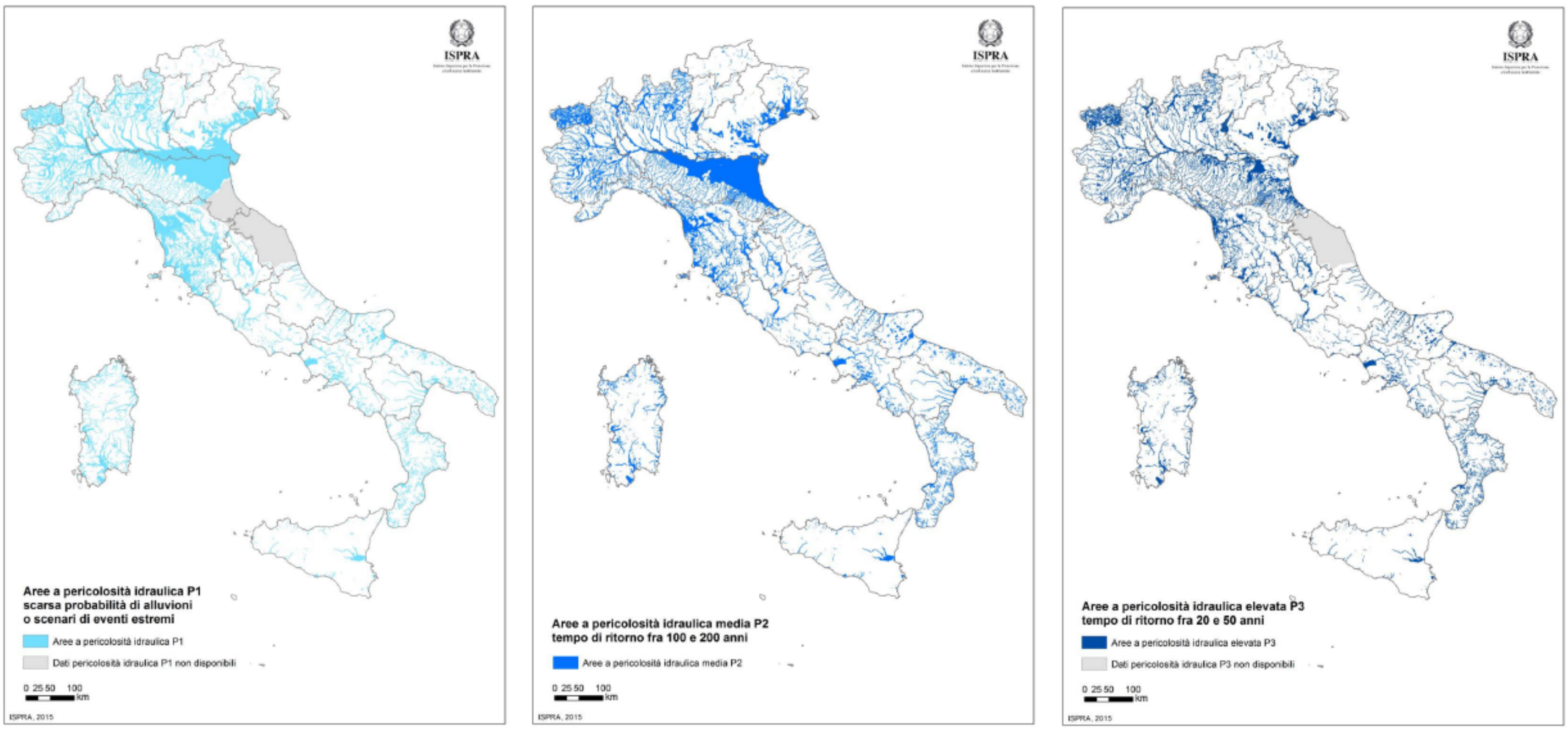

Figure 3.1: Categorization of the Italian territory in terms on flood risk- Left picture: low-risk areas (light blue color); center picture: medium-risk areas (blue color); right picture: high-risk areas (dark blue color). Grey lines indicate regions' borders. Source: Trigila et al. (2015)

of the national value added.[5]

In order to investigate the exposure of the banking sector to flood risk, we will only consider the fraction of LBUs at high-risk (i.e., those located in dark blue areas of Figure 3.1). The reason of this choice is that the investment horizon of banks is limited: in medium- and low-risk areas flood damages can be so infrequent that banks are unlikely to care of, while floods occurring once in 20 to 50 years (i.e., in high-risk areas) are sufficiently frequent to be considered by banks when financing firms' activities.

4 Empirical analysis

In this Section we explore the possible relationship between bank loans and flood risk. First, we explore data at municipal level and construct an indicator of catastrophe risk based on the fraction of LBUs exposed to high flood risk within each municipality. Second, we match data from the ISPRA report with proprietary bank lending data, commenting on Italian banks' exposure to catastrophe risk. Third, we investigate the determinants of bank loans to firms with a focus on the explanatory power of the catastrophe risk indicator, looking separately at performing and non-performing loans.

4.1 Catastrophe risk indicator

As Figure 3.1 clearly shows, flood risk is not only spread unequally among regions and provinces, but also *within* each province. The ISPRA dataset is available at municipal level, so we take the municipality as reference unit.[6] We define our measure of catastrophe risk per municipality j as the share of LBUs at high-risk of flood over the total number of LBUs located in municipality j:

$$\mathbf{CatRisk}_j = \frac{\text{LBUs at risk}_j}{\text{total number of LBUs}_j} \tag{4.1}$$

Figure 4.1 plots the distribution of Catrisk. The median of the distribution is very close to 0, confirming that risk is concentrated in a relatively small number of municipalities. The distribution is right-skewed, with risky municipalities having up to 40 percent of

[5]Statistics on landslide risk in the ISPRA report show, instead, that only 1.7 percent of LBUs is at high or very high-risk, with most of them located in only one region (Valle d'Aosta) producing the 0.3 percent of national value added. For this reason, in the rest of paper we just focus on flood risk, the most relevant hydrogeological risk for investment financing in Italy.

[6]Municipal data for high-flood risk areas, which are not present in the ISPRA report, are available from the *Italia Sicura* website of the Italian government.

firms at high-risk.

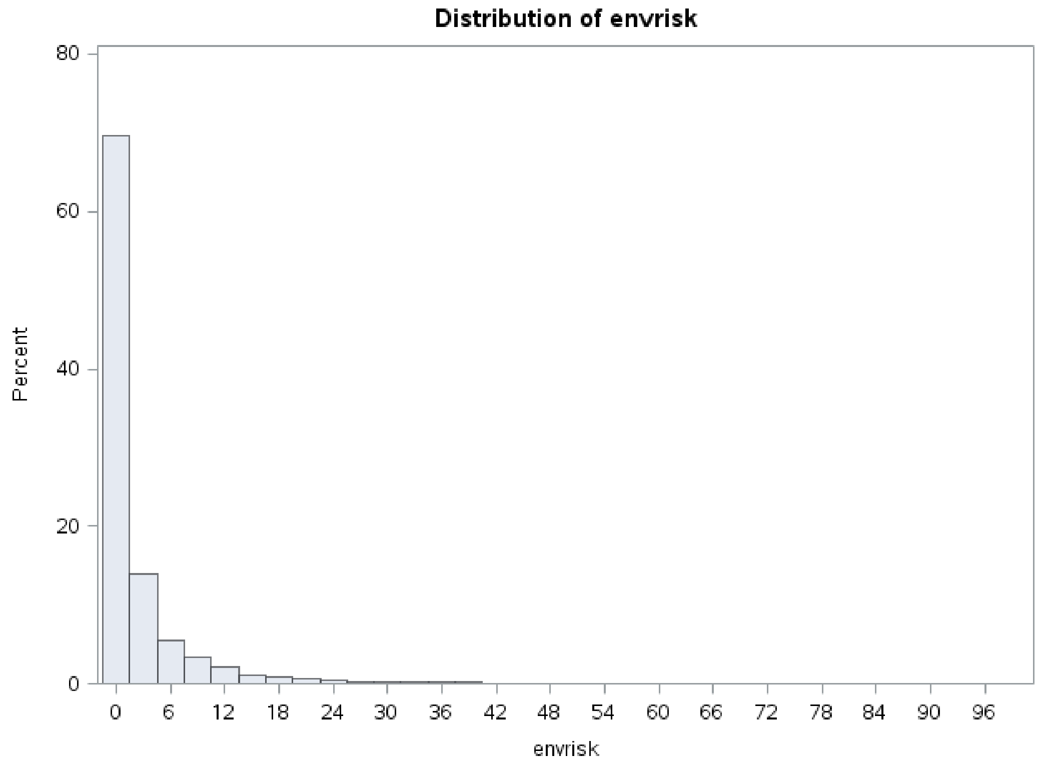

Figure 4.1: Municipal distribution of LBUs at high flooding risk (P3). Labels of the x-axis indicate the lower bound of each class.

In order to give a synthetic description of the per-municipality flood risk, we divide municipalities in two groups: the Low-Impact Flooding (LIF) one, which encompasses municipalities with lower share of exposed LBUs than the 75th percentile (around 3 percent), and the High-Impact Flooding (HIF) group, with equal or higher share of exposed LBUs than 3 percent.[7] Table 3 reports the number of LIF and HIF municipalities for each region. HIF municipalities are mostly concentrated in Piemonte, Lombardia and Emilia Romagna.

4.2 Bank loans to risky firms

If floods damage LBUs, firms can suffer business disruptions and fail to pay back their debt obligations. Therefore, financial intermediaries are exposed to natural catastrophes through their loans, other than through their own offices located in risky areas. This indirect channel should be relevant in Italy, provided that Italian firms mainly rely on

[7] The 75th percentile is arbitrarily chosen for illustrative purposes. This choice does not affect results in the regression analysis, which is carried out using the whole sample of data.

Region	LIF	HIF	Total
Abruzzo	290	15	305
Basilicata	128	3	131
Calabria	287	122	409
Campania	475	76	551
Emilia-Romagna	174	174	348
Friuli-Venezia Giulia	187	31	218
Lazio	340	38	378
Liguria	98	137	235
Lombardia	1228	316	1544
Marche	24	9	33
Molise	134	2	136
Piemonte	855	351	1206
Puglia	212	46	258
Sardegna	310	67	377
Sicilia	378	12	390
Toscana	155	132	287
Trentino	315	18	333
Umbria	65	26	91
Valle d'Aosta	24	50	74
Veneto	481	100	581
All	6160	1725	7885

Table 3: Municipal-level distribution for class of Flooding Impact in 2014. The High-Impact Flooding (HIF) class contains municipalities with share of exposed LBUs equal or greater than 3 percent; Low-Impact Flooding (LIF) municipalities are the remaining ones. Data on the remaining 170 municipalities are missing.

the banking system to raise external finance: indeed, for Italian non-financial companies bank debt represents about 70 percent of total debt, compared with 38 percent in France, 49 in Germany, and 30 percent in UK (Accetturo et al., 2013).

We investigate the indirect exposure of banks using loan data. Credit granted by banks operating over the Italian territory is collected by the Bank of Italy through its bank oversight activity. In order to be consistent with land categorization in the ISPRA report, we take data as of end-2014: at that time, the stock of outstanding loans was 1.9 trillion euros, of which 856 billion (the 47 percent) granted to the non-financial business sector. Considering only credit to non-financial business sector, we aggregate loan-level data by municipality in which the bank branch which granted credit is located, supposedly close to the final use destination of credit. Then, we match municipal data with our **Catrisk** indicator. Table 4 displays the amount of outstanding business loans as of end-2014 , divided by LIF and HIF municipalities. More than 20 percent of the total loan amount is granted in HIF municipalities, with the bulk of business loans at risk located in Lombardia, Veneto, Emilia Romagna and Tuscany.

The loan-level dataset from the Central Credit Register also contains information on

Region	LIF	HIF	Total
Abruzzo	9.763	1.037	10.801
Basilicata	2.040	18	2.059
Calabria	2.531	1.785	4.316
Campania	25.030	1.733	26.763
Emilia-Romagna	52.734	26.091	78.825
Friuli-Venezia Giulia	11.057	2.649	13.706
Lazio	64.498	2.006	66.504
Liguria	223	15.611	15.834
Lombardia	227.927	39.873	267.800
Marche	1.997	1.533	3.529
Molise	1.191	1	1.193
Piemonte	48.561	6.481	55.042
Puglia	15.261	2.950	18.211
Sardegna	4.927	2.814	7.740
Sicilia	18.366	37	18.404
Toscana	49.059	22.860	71.919
Trentino	20.161	1.847	22.008
Umbria	6.105	2.933	9.038
Valle d'Aosta	580	262	842
Veneto	51.587	29.435	81.023
All	613.601	161.956	775.557

Table 4: Bank loans to firms for class of Flooding Impact and Region: 2014 (mln euro).

the sector to which each borrower belong. Table 5 reports business loans, granted in LIF and HIF municipalities, by borrower sector.[8] About 60 percent of the loan amount in HIF municipalities is concentrated in four industries: Construction, Wholesale and Retail Trade, Real Estate activities and Basic Metals and Plastic Products.

4.3 A multivariate descriptive analysis

In this section, we analyze our environment-firm-credit dataset within a regression setup in order to estimate the elasticity of bank loans to the variation in flood risk at municipal level. We regress both the total amount of loans and the subset of performing loans on the natural logarithm of the **CatRisk** variable and controls. Using credit stocks instead of one-year flows, on one side we capture the historical relationship between lending and catastrophe risk, not conditional on economic and natural events related to one specific year of the sample; on the other side, we include loans made at times when the awareness on climate-related risks and the expertise to estimate them were very low. The estimates may therefore underestimate the existing link between catastrophe risk and bank lending.

[8]The sectorial breakdown is based on ATECO sectors, i.e. the adaptation of Eurostat's NACE sector classification to the Italian industry by the ISTAT.

#	Industry sector	LIF	HIF	Total
1	Mining	1.294	454	1.748
2	Food Products	22.462	6.105	28.567
3	Textiles	14.471	5.787	20.258
4	Wood and Products of Wood	9.229	2.694	11.923
5	Paper and Paper Products	6.874	2.134	9.009
6	Chemicals and Pharmaceuticals	12.173	2.592	14.764
7	Rubber and Plastic Products	7.932	2.025	9.956
8	Basic Metals and Metal Products	38.001	13.272	51.273
9	Electrical Equipment	8.751	2.174	10.924
10	Machinery and Equipment	16.490	4.787	21.276
11	Transport Equipment	7.795	1.718	9.512
12	Other Manufacturing	6.612	1.830	8.442
13	Electricity and Gas	33.882	5.608	39.490
14	Construction	106.765	30.639	137.404
15	Wholesale and Retail Trade	101.226	27.430	128.656
16	Transportation and Storage	34.246	5.903	40.149
17	Accommodation and Food Service	22.113	8.149	30.262
18	Information and Communication	13.031	1.556	14.587
19	Real Estate Activities	91.854	24.646	116.499
20	Professional Activities	25.929	5.596	31.525
21	Rental and Leasing Activities, Travel Etc	16.697	3.063	19.760
22	Other Service Activities	15.776	3.795	19.571
	All	613.601	161.956	775.557

Table 5: Banks loans to firms for class of Flooding Impact and Industry: 2014 (mln euros).

Defining the total loan stock as $TL = PL + NPL$, where PL (NPL) are performing (non-performing) loans, we estimate the following regressions:

$$\text{TL}_{j,h,k} = \beta_0 + \beta_1 \text{CatRisk}_{j,h} + \delta \, \textbf{controls}_{j,h,k} + \epsilon_{j,h,k} \tag{4.2}$$

$$\text{PL}_{j,h,k} = \beta_0 + \beta_1 \text{CatRisk}_{j,h} + \delta \, \textbf{controls}_{j,h,k} + \epsilon_{j,h,k} \tag{4.3}$$

where $\{j = 1, \ldots 7885\}$ indicates the municipality, $\{h = 1, \ldots, 108\}$ the province and $\{k = 1, \ldots, 23\}$ the borrower's industry sector; **controls** stands for control variables, which include 107 province dummies and 22 sectoral dummies.

4.4 Results

Table 6 reports the results of the estimation of Equation 4.2, where standard errors are clustered at province level. The percentage of business units at high-risk of flooding within each municipality has a significant, negative effect on bank lending: a one-percentage point increase in CatRisk entails a fall in the amount of total loans by 0,17 percentage points. This suggests that the catastrophe risk exposure can affect lending decisions or, more generally, credit availability. The regression has an R-squared of 0.13. With few exceptions, sectoral- and province-level dummies are significant at the one percent level (not reported in table), entailing strong relationship of lending activity with the geographic destination of loans and type of industry.

Results of Equation 4.3 are displayed in Table 7. The coefficient of **Catrisk** is slightly higher than that in Table 6, showing that the relationship is stronger in the case of performing loans only.

Dependent variable: TL						
Parameter	Estimate	Std Err	t Value	p-value	95% Conf Int	
Intercept	- 0,755	0,041	- 18,310	<.0001	- 0,836	- 0,673
CatRisk	- 0,166	0,029	- 5,660	<.0001	- 0,224	- 0,108
controls:						
Industry sector fixed effects	Yes					
Province fixed effects	Yes					
R-square	0.128					

Table 6: Regression of total loans (PL+NPL) on CatRisk and controls. Total loans and CatRisk are in natural logarithm. Standard errors are clustered at province level (108 clusters). Observations are 110,388.

Dependent variable: PL						
Parameter	Estimate	Std Err	t Value	p-value	95% Conf Int	
Intercept	- 0,135	0,043	- 3,120	0,002	- 0,221	- 0,049
CatRisk	- 0,176	0,031	- 5,640	<.0001	- 0,238	- 0,114
controls:						
Industry sector fixed effects	Yes					
Province fixed effects	Yes					
R-square	0.162					

Table 7: Regression of PL on CatRisk and controls. PL and CatRisk are in natural logarithm. Standard errors are clustered at province level (108 clusters). Observations are 69,232.

4.5 Robustness analysis at province-level

Our municipal level dataset does not allow us to control for bank and firm size, as well as for local value added that is not reported at municipal level. On the bank side, big banks can be more able to diversify risk, screen firms and absorb losses, but also have different internal decision processes and relationships with their customers; on the firm side, small and medium enterprises can be less resilient to floods than larger firms, also because they have less business units and those are geographically closer to each other (so they have less room to diversify catastrophe risk than large firms).

We conduct a robustness analysis by using credit data from a different proprietary dataset, based on surveillance reports of banks to the Bank of Italy, which allows for a wider set of controls. This dataset aggregates loans to firms at province level, imputing loans to the province in which the firm is legally resident. The province scale and the imputation by firm residence constitute two limitations of this data source. We construct a measure of catastrophe risk at province level ($\mathtt{CatRisk}^{\mathtt{prov}}$) and, using the province-level stocks of performing and non-performing loans ($\mathtt{PL}^{\mathtt{prov}}$ and $\mathtt{NPL}^{\mathtt{prov}}$), run the following regressions

$$\mathtt{PL}^{\mathtt{prov}}_{p,q,r,s,u} = \beta_0 + \beta_1 \mathtt{CatRisk}^{\mathtt{prov}}_{p,q} + \gamma\, \mathbf{controls}^{\mathtt{prov}}_{p,q,r,s,u} + \delta\, \mathbf{int}^{\mathtt{prov}}_{p,q,r,s,u} + \epsilon_{p,q,r,s,u} \tag{4.4}$$

where $\{p = 1,\ldots,110\}$ identifies the borrower's province of residence, $\{q = 1,\ldots,20\}$ the region of residence, $\{r = 1,2\}$ identifies the bank type (i.e., 1 = small bank, 2 = big bank, 3 = non-classified banks), $\{s = 1,2,3\}$ the type of borrower (i.e., 1 = small and medium enterprises, 2 = large non-financial firms, 3 = producer households), $\{u = 1,\ldots,23\}$ the borrower's industry sector; $\mathbf{controls}^{\mathtt{prov}}$ stands for control variables, and $\mathbf{int}^{\mathtt{prov}}$ for interaction terms.

Control variables are:

- a firm-size dummy for small-medium enterprises (*SME*);
- two bank-size dummies (*BigBanks* and *SmallBanks*);
- 22 sector dummies, to disentangle differences in the credit granted among provinces related to the sectoral specialization of each province from differences due to flood risk considerations;

- the 2013 sectoral value added for the two macro-sectors (manufacturing and services) at province level ($\log(VAManuf2013)$ and $\log(VAServ2013)$): higher valued-added provinces might demand a different amount of credit than lower value-added ones;
- 19 regional dummies: regional characteristics (e.g., the presence or lack of specific public spending programs at regional level) can positively or negatively affect the business environment, so the propensity of banks to lend to firms that operate in that environment;

Interaction terms are included to control for possible combined effects between variables. The firm-size dummy is interacted with the bank-size ones to control for combined bank-firm characteristics; the catastrophe risk variable is interacted with bank dummies to identify correlations between bank lending and catastrophe risk that are limited to specific bank types (i.e., small or bigs) or firm type (i.e., small and medium enterprises).

Table 8 reports the results for the specification in Equation 4.4. The regression has an R-squared of 0.2. Also in this case, sectoral and regional dummies are significant at the one percent level. The dummy for small- and medium-size enterprises has the expected negative sign, meaning that an increase in the share of small and medium enterprises is associated with a reduction in the total amount of loans; on the contrary, the coefficients of the two bank-size dummies are both positive, meaning that bank loans are higher for big and small banks compared with medium-sized banks. As bank and firm dummies, the sectoral value added dummies are also significant at the 1 percent level.

Bank lending is positively correlated with the CatRisk variable and it is negatively correlated with the dummy SME; this negative SME effect increases with catastrophe risk indicating that bank lending further decrease for the SMEs that are located in high-risk flooding areas. The latter result is in line with the municipal level analysis, and reflect the fact that the imputation of credit in the two analyses may be similar in case of small and medium-size firms, which are likely to have a legal residence that is close to the places in which credit is granted (and used). Assuming the imputation of credit to big firms is not biased, the joint result for the two coefficients may suggest that banks take into consideration catastrophe risk in their loan decisions only in the case the borrower is a small or medium enterprise, because the latter is considered to be less resilient to natural catastrophes. Another interesting result is that CatRisk is positively correlated with bank lending in case of loans being granted by big banks: big banks lend more to risky areas, maybe because firms hit by floods demand credit mainly to them to rebuild damaged industrial sheds.

Dependent variable: PL_province						
Parameter	Estimate	Std Err	t Value	p-value	95% Conf Int	
Intercept	8.499	0.063	134.9	<.0001	8.376	8.623
CatRisk_province	0.034	0.010	3.6	0.000	0.015	0.053
controls:						
SME	- 1.248	0.019	- 65.7	<.0001	- 1.286	- 1.211
BigBanks	1.801	0.022	80.9	<.0001	1.757	1.844
SmallBanks	0.260	0.021	12.2	<.0001	0.219	0.302
SME*BigBanks	- 0.917	0.025	- 36.6	<.0001	- 0.966	- 0.868
SME*SmallBanks	- 0.016	0.024	- 0.7	0.515	- 0.063	0.032
CatRisk_province*SME	- 0.031	0.008	- 4.0	<.0001	- 0.047	- 0.016
CatRisk_province*BigBanks	0.039	0.009	4.2	<.0001	0.021	0.057
CatRisk_province*SmallBanks	0.007	0.009	0.8	0.449	- 0.011	0.025
log(VAmanuf2013)	0.151	0.013	11.4	<.0001	0.125	0.177
log(VAserv2013)	0.314	0.013	24.4	<.0001	0.289	0.339
Industry sector fixed effects	Yes					
Regional fixed effects	Yes					
R-square	0.2193					

Table 8: Regression of PL on CatRisk, controls and interaction terms. PL and CatRisk are in natural logarithm. Observations are 211,870.

Unfortunately our source loan-level dataset does not include information on the interest rate applied to each loan. The costs of loans can in principle be used to discriminate across firms located in risky areas; however, if there is credit rationing for firms exposed to flood risk, we could safely ignore it on the ground of the evidence according to which banks might rather set below-average rates and ration credit than increase interest rates when facing an increased demand (see the literature review in Kirschenmann (2016)).

4.6 Insurance coverage

In the previous regressions we did not control for the possibility that firms can be insured against flooding, because data on flood risk insurance, as well as data on general catastrophe risk insurance coverage, are not available for the Italian business sector. The insurance coverage may be a relevant omitted variable: indeed, if one firm is insured against floods, banks may ideally *choose* to ignore its exposure to flood risk when granting loans, knowing that physical damages are reimbursed by the insurance. While this hypothesis may sound naive, provided that firms suffer business disruptions in case of floods (and can become unable to repay loans) no matter whether they are insured or not, it cannot be ruled out.

To gain insights on this topic, we added two specific questions in the 2016 edition of the Survey of Industrial and Service Firms and Business Outlook conducted on an annual basis by the Bank of Italy. In particular, we asked the following two questions:

- Question 1: *Has your company suffered losses or spent money to restore its business because of floods or landslides during the last five years?* (Possible answers are: Yes; No; I dont' know/I don't want to answer)
- Question 2: *Are your business units and machinery insured against floods or landslides?* (Possible answers are: No, but we will do it; No, and we will not do it; Yes)

Results are reported in Table 9 and 10, where missing answers in the two questions are imputed using standard statistical procedures. Of the whole set of interviewees, the 5.3 percent has been hit by a hydrogeological event between 2012 and 2016, with the majority of them in the industry sector and located in the north-west and in the center of Italy; the 44 percent of interviewees is insured against damages caused by floods or landslides, with a lower insurance coverage in the South of Italy and for smaller firms.[9]

[9]Interestingly, by crossing information on Question 1 and Question 2, you get that not all firms that have suffered losses related to landslides and floods between 2012 and 2016 were planning to insure against

Geographic area and size	Industry	Services	Total
North-west	8.4%	5.2%	6.9%
North-east	3.8%	2.5%	3.2%
Center	6.7%	5.8%	6.2%
South	5.9%	3.5%	4.4%
20-49	5.9%	3.4%	4.6%
50-99	6.4%	5.6%	6.0%
100-199	6.2%	5.4%	5.9%
200-499	9.9%	7.6%	8.7%
500-999	10.6%	13.1%	12.0%
1000+	12.8%	15.8%	14.7%
Total	6.3%	4.4%	5.3%

Table 9: Percentage of the interviewed companies which suffered losses or spent money to restore their business because of floods or landslides between 2012 and 2016, by geographic area, number of employees and sector (Question 1).

Geographic area and size	Industry	Services	Total
North-west	50.4%	41.4%	46.9%
North-east	51.0%	42.6%	47.3%
Center	44.1%	44.1%	44.1%
South	39.2%	28.7%	32.7%
20-49	43.1%	38.5%	40.7%
50-99	54.0%	39.0%	46.6%
100-199	59.1%	44.4%	51.9%
200-499	65.7%	42.2%	53.6%
500-999	66.3%	52.4%	58.4%
1000+	66.8%	53.6%	58.3%
Total	48.0%	39.6%	43.7%

Table 10: Percentage of the interviewed companies which was insured against floods or landslides as of 2016, by geographic area, number of employees and sector (Question 2).

these types of events in the future. The complete set of results from Question 1 and 2 are available upon request.

All in all, results from the Survey indicate a low insurance penetration in the Italian business sector. This is relevant for our analysis, also because the Survey targets firms with 20 or more workers, while the average dimension of Italian firms is 3.7 workers (according to ISTAT): if one reasonably assumes that small firms are less incline to buy insurance against catastrophe events than big ones, as it is evident in the Invind data (e.g. because insurance premia are relative more expensive for SMEs), the percentage of insured firms in the population of Italian firms is actually lower than that obtained in the Survey's sample. This suggests that the omission of insurance coverage in our regressions should not seriously bias the estimator adopted.

5 Conclusions

We make an empirical assessment of the risk borne by the Italian banking sector through its exposure to firms located in areas at risk of flooding. For this purpose, we match a new mapping of flood risk areas over the Italian territory with proprietary bank lending data. We construct a measure of flood risk as the share of firms located in high-flood risk areas within each municipality and test whether the amount of bank credit granted to firms depends on the level of flood risk. We find that lending activity is negatively correlated with catastrophe risk, and results are confirmed for loans granted to small and medium enterprises in a robustness analysis at the province level. Our results are compatible with the hypothesis that credit activity could be somehow influenced by catastrophe risk and open to new research on the topic: while there is no identification of demand and supply drivers of credit, our results may suggest that banks can discriminate borrowers by their catastrophe risk exposure. This study proposes a classification of the entire stock of credit in one economy by climate-related riskiness of the borrower, that can be used to track climate-related risk perception over time. Indeed, based on publicly available information on the degree of flood risk by geographic areas, it allows to give insights on the *ex-ante* perception of risk, without making inference from the ex-post behavior of agents.

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