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Creative Disasters? Flooding Effects on Capital, Labour and Productivity Within European Firms

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Abstract This paper examines the impact of floods on the firms' capital accumulation, employment growth and productivity by using a difference-in-difference (DID) approach and considering the firms' asset structure. We find evidence that, in the short run, companies in regions hit by a flood show on average higher growth of total assets and employment than firms in regions unaffected by flooding. The positive effect prevails for companies with larger shares of intangible assets. Regarding the firms' productivity a negative flood effect is observable which declines with an increasing share of intangible assets.

Keywords Climate change · Natural disasters · Firm growth · Productivity · Difference-in-difference

JEL Classification D24 · Q54 · R10 · C21

1 Introduction

Natural disasters such as hurricanes or floods occur every year and leave their mark on landscape, population and industries. It is often stated that climate change will induce even

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more frequent and severe extreme weather events. In its fourth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) points at possible consequences of natural hazards for humanity due to climate change. Different phenomena of climate change and their possible impacts on various sectors (agriculture, water resources, human health, industry) are discussed (Parry et al. 2007).

In this paper, we pick one argument mentioned in the IPCC report and focus on the effects of floods on the activities of firms in Europe. We analyse the effects of floods on physical capital accumulation, employment and productivity using cross-sectional data of European companies. We also take into account the idea of different degrees of resilience of different elements of the capital stock. Using a difference-in-difference (DID) approach we find that physical capital accumulation and employment growth, *effect on input factors*, is significantly higher in regions experiencing a major flood-event. The positive effect prevails for companies with a high share of intangible assets (e.g., R&D, patents, software, trademarks). Regarding productivity, *effect on productivity*, a negative impact of a major flood is observable, which declines with an increasing share of intangible assets.

The following sections describe the procedure and findings in detail. We start with an overview of related literature in Sect. 2. Section 3 discusses the model and the econometric procedure, Sect. 4 presents the data and descriptive statistics, Sect. 5 provides the estimation results. Finally, Sect. 6 concludes.

2 Literature Review

According to the IPCC assessment a warmer climate can considerably change precipitation in many regions worldwide. It is likely that heavy precipitation will occur and that its frequency will increase over most areas (Schröter et al. 2005; Christensen and Christensen 2002). As the recent IPCC report states, such events would adversely affect food production, water supply and, hence, also negatively influence human health. Disruption of business activities and a loss of property are mentioned as negative consequences for the industrial sector. However, while there is no doubt that disasters are accompanied by human suffering, recent studies indicate that the consequences of natural hazards on aggregate output can be positive.

The general findings in the existing empirical literature on the impact of disasters on output can be summed up as follows: As a direct effect, natural disasters physically destroy the factors of production—labour (e.g., Anbarci et al. 2005; Kahn 2005; Halliday 2006) and physical capital (Albala-Bertrand 1993). These direct impacts cause business interruptions within the affected firms and set off additional indirect effects on companies up- and downstream in the supply chain (Rose 2004). The aftershock period can follow several paths that have been simulated in a numerical model by Tol and Leek (1999). If lost capital is not replaced the level of production is permanently lowered. Given that the destroyed capital stock is replaced, the output might just drop in the immediate aftermath of the event and then increase at an even higher rate. Economic scholars (e.g., Crespo-Cuaresma et al. 2008; Okuyama 2003; Skidmore and Toya 2002) largely agree that the major impetus for this rise in the output-rate comes from an update in technology and/or factor composition. Furthermore, several authors also highlight the possibility of positive employment effects (Skidmore and Toya 2002; Ewing et al. 2003, 2007).

The magnitude of the disaster effect on a firm is not solely determined by the magnitude of the natural process itself (e.g., Richter-scale, water level) but also by company-specific factors, such as investment strategies (Tol and Leek 1999; Skidmore and Toya 2002), factor composition, the level of technology (Crespo-Cuaresma et al. 2008) and disaster relief

(Sobel and Leeson 2006; Shughart 2006). Okuyama (2003) puts forward that older capital stock is more vulnerable to natural disasters and suggest distinguishing between effective and productive capital when analyzing short-term effects of disasters on production.

So far, only a few scholars have emphasized short-run effects in their empirical analyses and have mostly focused on a single aspect such as employment effects (Ewing et al. 2007) or productivity (Raschky 2007). In the analysis of the effects of sudden disaster shocks, Hallegatte et al. (2007) point out the caveats of applying the standard Solow growth framework, with its clear long-run perspective. Murlidharan (2003) shows in various simulations that the change in capital assets depends on the time elapsed after a hazardous event has occurred. This supports the assumption that short-run and long-run analyses may come to different conclusions regarding the impact of disasters on firm performance.

Our study thus augments the existing empirical literature on natural hazards and growth by emphasizing the firm level effects regarding input factors and productivity resulting from disasters in the immediate aftermath of an event. However, differing from previous empirical analyses, we explicitly control for different levels of flood exposure of capital assets by distinguishing between tangible and intangible assets. Furthermore, most of the previously mentioned studies examine the long-run economic effects of natural disasters on performance using highly aggregated data. This paper focuses on the short-run flood effects on European firms by using *individual* information of companies in flooded regions. Hence, contrary to examining aggregated data (e.g. at an industry or country level) we are able to consider flood effects on the firms' average performance at a rather disaggregated level. To our knowledge there has been no empirical study so far that has estimated the short-term effects of natural disasters applying data at the firm or plant level.[1]

3 Empirical Strategy

In our empirical analysis we distinguish between affected and non-affected plants via their location in flooded and non-flooded regions, respectively. In other words, plants are classified as 'affected by a flood' when they are located in a European region where a major flood occurred in 2000. It is important to notice that not all firms in a flood region are necessarily physically hit by the event. Limiting the analysis only to firms directly hit would deliver an incomplete picture of flood losses at the plant level within regions. In contrast to the division between direct and indirect effects (e.g. Rose 2004), our emphasis lies on the cumulative impact of a major flood on input factors and productivity at the firm level. This allows us to draw a more comprehensive picture of the consequences of floods at the firm level by considering direct effects through physical destruction as well as indirect effects via supply-chain linkages, reconstruction activity and replacement production in other plants within the region.

3.1 Estimation Procedure

Our analysis focuses on three different dependent variables: (i) the physical capital stock measured via the firms' total assets, (ii) employment expressed as the number of employees and (iii) productivity depicted as value added. While the assets and employment estimates analyse the effects on input factors of floods, the production function refers to effects of

[1] In this study either unconsolidated firm level data or lone-standing firm information is used to examine average regional effects of a flood event. Therefore, our data are comparable to plant level information.

floods on productivity. We infer our empirical model of physical capital accumulation and employment growth from firm size and firm growth literature (e.g., Evans 1982; Sutton 1997; Fotopoulus and Louri 2004). In these studies, initial values of the firm size and the age of the company explain the current size of a firm.[2] The effect of hazards on productivity is examined using a procedure analogous to the Cobb-Douglas production function framework.

The econometric implementation follows the DID approach described in Wooldridge (2002). To analyse which factors determine physical capital accumulation and employment growth we run OLS and IV (2SLS) regressions for both, the physical capital stock and the employment level, as mentioned in Eqs. 1 and 2. Both equations state that firm size follows an AR(1), where the growth rate becomes independent of firm size when $\beta_1 = 1$ or $\gamma_1 = 1$.[3]

We take the logarithm of all continuous variables before we include them in the regression functions. In the OLS case we regress total assets (*ltoas*) and number of employees (*lempl*), respectively, on its corresponding initial value (*ltoasi*) or (*lempli*), firm's age (*lage*), share of intangible assets (*SIA*)[4], time (*time*), treatment (*treatment*) and DID (*DID*) dummies, the interaction of the share of intangibles with the DID dummy (*SIA*DID*), industry (*ind*) and country (*country*) specific effects and on a constant:

$$\begin{aligned} ltoas_{ijrct} &= \beta_0 + \beta_1 * ltoasi_{ijrc} + \beta_2 * lage_{ijrc} + \beta_3 * SIA_{ijrct} + \beta_4 * time_t \\ &\quad + \beta_5 * treatment_r + \beta_6 * DID_{rt} + \beta_7 * (SIA * DID)_{ijrct} \\ &\quad + \varphi * ind_i + \iota * country_c + \epsilon_{ijrct} \qquad (1) \\ lempl_{ijrct} &= \gamma_0 + \gamma_1 * lempli_{ijrc} + \gamma_2 * lage_{ijrc} + \gamma_3 * SIA_{ijrct} + \gamma_4 * time_t \\ &\quad + \gamma_5 * treatment_r + \gamma_6 * DID_{rt} + \gamma_7 * (SIA * DID)_{ijrct} \\ &\quad + \lambda * ind_i + \kappa * country_c + \nu_{ijrct} \qquad (2) \end{aligned}$$

The indices represent a company i in industry j located in region r[5] in country c at period t.[6] In the IV regression we instrument the initial capital (labour) values using (i) the average amount of total assets (average number of employees) in each NACE 3-digit industry and (ii) the industry specific minimum efficient scale.[7] A Hausman specification test is used to identify the appropriate model.

The model for productivity is embedded in a Cobb-Douglas production function framework and is regressed on a constant, on capital (*ltoas*) and labour (*lempl*) inputs, ratio of intangible assets to total assets (*SIA*), interaction of this share of intangibles with the DID estimator (*SIA*DID*), and DID (*DID*), time (*time*), treatment (*treatment*), industry (*ind*) and country (*country*) dummies:

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[2] The empirical firm size literature focuses on the evolution of the firm size distribution for a given age cohort over time and therefore concentrates on cross sectional variation in firm size (e.g. Cabral and Mata 2003). The major finding in this literature is that the initially skewed firm size distribution for a given age cohort becomes more symmetric over time (i.e. firms tend to converge to an efficient firm size level).

[3] Subtraction of $\beta_1 * ltoasi_{ijrc}$ from (1) and $\gamma_1 * lempli_{ijrc}$ from (2) leads to formulations of changes in tangible assets and employment growth.

[4] The share of intangible assets is calculated using differences in logs of intangible assets and total assets. Therefore, this variable takes on negative values only.

[5] In this paper region is defined in terms of exposure, i.e., the dummy describes the flood and non-flood regions.

[6] i varies between different estimation equations and ranges from 82,010 (employment) to 111,657 (productivity); j from 1 to 103; c from 1 to 4; $r = 1{,}2$ and $t = 1{,}2$. The initial size variables do not vary over time. Age is constructed relative to a reference year and is therefore constant before and after the flooding but varies across companies.

[7] Our measure of minimum efficient scale (MES) is the 50th percentile of the initial total assets (employment) distribution within a NACE industry within our data sample and is therefore only a proxy for the real MES.

$$\begin{aligned} y_{ijrct} = \ & \delta_0 + \delta_1 * ltoas_{ijrc} + \delta_2 * lempl_{ijrc} + \delta_3 * SIA_{ijrct} + \delta_4 * time_t \\ & + \delta_5 * treatment_r + \delta_6 * DID_{rt} + \delta_7 * (SIA * DID)_{ijrct} \\ & + \phi * ind_i + \upsilon * country_c + \eta_{ijrct} \end{aligned} \tag{3}$$

with y, $ltoas$ and $lempl$ representing logs of value added, total assets and number of employees, respectively. Again, i, j, r, c and t index company, industry, region, country and period, respectively.[8]

Estimation of productivity effects at the firm or plant level induces econometric problems. A firm has—at least to a certain extent—information on its productivity when choosing the level of factor inputs. Therefore, the factor input decision is not independent of firm specific productivity which induces a simultaneity bias. Olley and Pakes (1996) and Levinsohn and Petrin (2003) provide estimation procedures which allow a consistent estimation of production functions using panel data. Unfortunately, the approaches suggested are unfeasible due to data limitations and the cross sectional focus of our estimation approach. However, we try to control for the simultaneity problem by using average inputs at an industry-region level for the endogeneous inputs as instruments in the production function and compare the IV results with the OLS approach via the Hausman specification test.

3.2 Explanatory Variables

In the physical capital and employment regressions, we include the initial values of physical capital and employment, respectively, and the age of the firm defined as the time span between the company's foundation and the reference year 1999. Productivity is regressed on total assets and employment. The other explanatory variables included are the same for the inputs as well as for productivity equations: For all three specifications, we consider a repeated cross section for two time periods—before and after flooding—and split our sample into two groups – flooded and non-flooded regions. The former represents the treatment group and the latter defines the control group. The time dummy which equals 1 for the period after the flooding and equals 0 otherwise, allows us to account for average changes over time which are relevant for both groups. The treatment dummy—1 if a firm is located in a region hit by a major flood, 0 otherwise—controls for initial differences between the treatment and control group. The econometric advantage of using a flooding as treatment is its exogeneity[9] as the occurrence of such an event is independent of study designs and country specific characteristics.[10] The interaction of the time and flood dummy represents the DID estimator.

[8] Alternative approaches to estimate disaster losses are Input-Output Models (I-O) and Computable General Equilibrium Models (CGE). I-O Modelling has dominated the literature (e.g. Rose et al. 1997) and is also widely used by public authorities to evaluate disaster impacts [e.g. Federal Emergency Management Agency (FEMA) 2004]. Rose and Liao (2005) used a CGE model to estimate the regional economic impacts of disruptions in the water services of the Portland (Oregon, US) metropolitan area. For a detailed discussion on the advantages and drawbacks of each method see Rose (2004).

[9] If previous flood events had affected firms' behaviour before the 2000-flood such influences would be captured via the industry, region and country fixed effects. It might be possible that such responses to previous floods might determine the consequences of future flood effects as, for example, precautions taken will certainly influence the severity of damages. However, a single firm's activity cannot change the incidence and frequency of natural disasters.

[10] We are aware that the inclusion of a flood event in the EM-DAT database may, for example, correlate with a country's ability to prevent floods and/or mitigate their potential for damage and thus directly affect the event's magnitude. However, as the classification of an event as natural disaster does not solely depend on (financial) damages but also on other consequences (e.g., fatalities, people affected, state of emergency) and as the group of countries considered is rather homogeneous in terms of economic development we think that

It equals 1 for the treatment group members in the after flood period and is 0 otherwise. This estimator solely measures the flood effects on the input factors and on productivity, respectively, since we control for the general group- and time-specific effects via the time and treatment dummies. The share of intangible assets in total assets derived from the balance sheets and an interaction term of the DID dummy with the share of intangibles are further explanatory variables used in all three equations. The motivation for the inclusion of the interaction term stems from the assumption that particularly the short-run consequences of floods on capital accumulation and employment changes may differ depending on the vulnerability of the input factors.

The idea of splitting capital into two parts is also in line with Hallegatte et al. (2007), who propose to introduce an additional term into the Cobb-Douglas production function to control for the destruction of effective capital. Rather than distinguishing between effective and potential productive capital we differentiate between tangible and intangible assets and include the share of intangible assets in our production function. Tangible assets can be defined as factors which are potentially exposed to physical destruction. Contrary, physical destruction is not relevant for intangibles and their economic depreciation may therefore be lower. Hence, we assume that tangible (intangible) assets are more (less) exposed to floods. Furthermore, we doubt that the impact of intangibles on productivity is the result of an updating process. Rather, as intangible assets are often an outcome of R&D activities (patents, licenses) they may act as a multiplier which promotes (softens) positive (negative) tendencies.

4 Data and Descriptive Statistics

The investigation of immediate effects of natural disasters on the firms' input factors and productivity requires data on the firms' performance as well as information on natural disasters. The data on the natural disaster event (flood) is provided by the EM-DAT dataset collected by the Centre for Research on the Epidemiology of Disasters (CRED) in Brussels. A flood event has to fulfil at least one out of the following criteria in order to be included in the EM-DAT: 10 or more deaths, 100 or more affected people, declaration of a state of emergency or a call for international assistance as a consequence of the flood incident (see Raschky 2007). The EM-DAT database also includes more detailed information on the affected locations within a country which is used to identify the regions actually hit by a flood. Regarding this regional dimension we choose NUTSII-level[11] as this is the most disaggregated level that allows an accurate spatial assignation of the flood event at a regional level.[12] Worldwide, floods accounted for about 25% of the total number of large scale disasters between 1950 and 2007. In Europe, floods are the second largest natural disaster (after wind storms), in terms

Footnote 10 continued
the inclusion of an event in the database is rather independent of country specific characteristics so that the classification of floods as an exogenous treatment should be justified.

11 Eurostat established the breakdown of territorial units into NUTS (Nomenclature of Territorial Units for Statistics) regions. Within this concept each EU member state can be divided into 3 NUTS regions, with NUTSIII (NUTSI) representing the most aggregated (disaggregated) one. For detailed information on the NUTS classification see http://ec.europa.eu/eurostat/ramon/nuts/home_regions_en.html.

12 The average size of the NUTSII-regions in our sample is 17,842 km^2, with an average population density of 375 inhabitants/km^2. The sub-sample of regions affected by flood has on average an average area of 14,113 km and 204 inhabitants/km^2. The per capita income in the flood regions is slightly higher at EUR 17,514 (1995 PPP) than in non affected regions (EUR 16,799) and is similar to the EU-mean of EUR 17,327 in 2000. A map depicting the affected NUTSII regions can be found in the appendix.

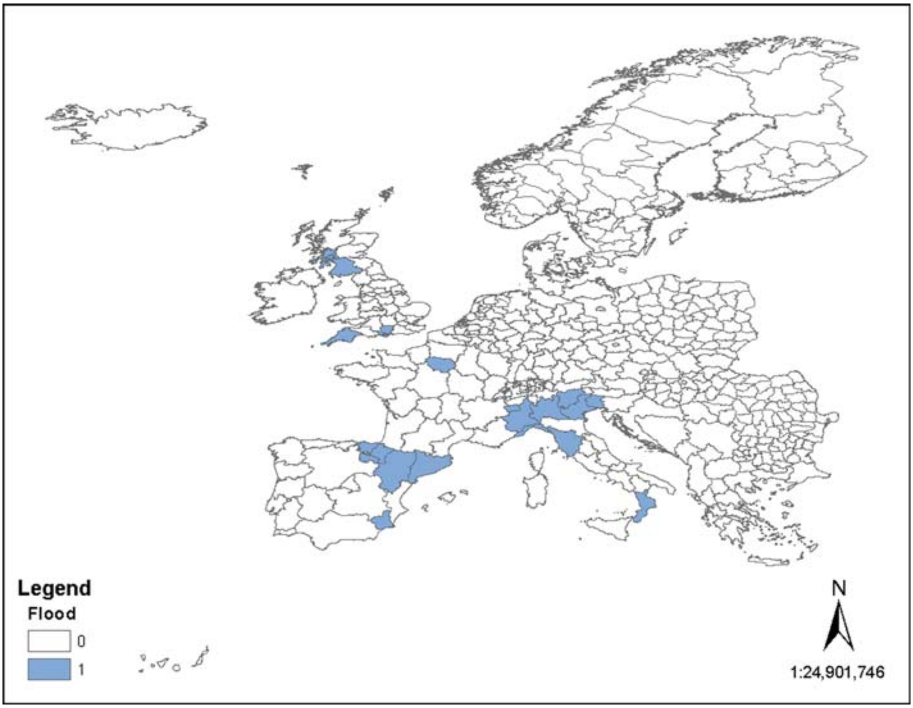

Fig. 1 NUTSII-regions hit by the 2000 floodings

of the total number of events, accounting for about 33% of all natural catastrophes [Center for Research on the Epidemiology of Disasters (CRED) 2007].

Within the observed time period a major flood took place in the year 2000 and affected 30 out of 268 NUTSII regions in Europe. The following 20 NUTSII-regions (Fig. 1) in our sample were only affected by major flood events in the year 2000:[13] Spain: Pais Vasco, Navarra, La Rioja, Aragon, Cataluña Region de Murcia; France: Ile de France; Italy: Piemonte, Valle d'Aosta, Liguria, Lombardia, Bolzano, Trento, Veneto, Friuli-Venezia Giulia, Toscana, Calabria; U.K.: Hampshire, Cornwall, South Western Scotland. The 2000 floods in Europe were among the most severe in recent years and caused large human losses as well as material damages. In order to give the reader an impression of the magnitude of the flood events, we present some anecdotal evidence from the different countries.

Northern Italy was hit by severe rainfalls in October 2000 that directly affected about 43,000 people and resulted in an estimated damage of EUR 8 bill. in the regions of Piémont, Val d'Aoste, Ligurie [Center for Research on the Epidemiology of Disasters (CRED) 2007]. According to media reports about 30 factories were damaged near Turin alone and Italy's biggest car-producer had to close three of its largest factories for several days.

According to reports by Risk Management Solutions (RMS) the flood events in October and November 2000 were among the most severe since 1947. Approximately 11,000 homes

[13] All companies in regions where another flood event occurred before and/or after 2000 are eliminated from the data sample to isolate the average effect of one single flood. However, to check the robustness of our estimation results we also estimate the input factor equations and the productivity equation by including firms which were affected by several flood events within the observed time span. The corresponding results are shown in the Tables 9 (input factors) and 10 (productivity) in the appendix.

Table 1 Number of firms listed by country

Country	Number of firms	Percent
France	31,231	22.77
Italy	68,082	49.63
Spain	30,052	21.91
United Kingdom	7,819	5.70
Total	137,184	100.00

and commercial sites were flooded at 700 locations around the UK with estimated insured losses of about EUR 800 millions [Risk Management Solutions (RMS) 2000a,b]. Data from the EM-DAT suggest that during the October 2000 flood in the UK about 69% of the total area of our sample regions were under water. In particular, during the October 2000 flood in the Southern UK a large proportion of affected properties included businesses and industrial estates.

Heavy rainfall in northern Spain caused the flooding of an area of approx. 26,700 km^2, killing 16 people and resulting in an estimated damage of EUR 75 Mill. [Center for Research on the Epidemiology of Disasters (CRED) 2007]. Earlier that year, a flash flood in June caused an estimated damage of EUR 65 Mill in the region of Cataluña (Llasat et al. 2003).

The firm level data are provided by the AMADEUS Database.[14] As mentioned above, we have to rely on data from lone-standing firms and unconsolidated balance sheet and profit and loss data to assure that the observed units have been affected by the flood event. In the final dataset we focus on manufacturing companies to make sure that only enterprises which use potentially destructible capital stocks in their production processes are considered.

The AMADEUS and EM-DAT databases are merged using the information about the regional location of the companies and the regional occurrence or non-occurrence of flood events. The resulting dataset includes data of 6 years which are finally pooled as pre- and post-flood averages (i.e. the years 1997 until 1999 from the pre-flood period and the years 2000 until 2002 are used to construct the post-flood period).

Table 1 shows the number of manufacturing firms located in countries where at least one region was affected by a flooding in 2000. Firms in flood regions define the treatment group while all other companies in the non-flooding regions represent the control group.[15] Firms located in countries unaffected by a flood in 2000 are not included in the final dataset in order to reduce unnecessary large cross-country variation in the data. For a DID estimation, the treatment and the control group should be approximately balanced in terms of sample size. Table 2 reveals that the treatment (affected) and control groups (non-affected) are well balanced.

Table 3 reports the mean, standard deviation, minimum and maximum of the dependent variables in the estimated models. Companies which are located in the non-flooded regions are larger in terms of labour. On average, firms in these regions also tend to be more productive than firms in flood-affected regions. Total assets, employment and average productivity

14 The Bureau van Dijk distributes the AMADEUS database which includes financial statements, profit and loss accounts and information on companies' organizational structure of 8.8 million firms located in 40 European countries.

15 Disasters will not only have an influence on firms in regions hit by a flood but will also influence their suppliers and customers. Unfortunately, due to data constraints, it is not possible to control for different steps in the supply and buyer chain of companies and to distinguish whether the suppliers and buyers are located in flooded or non-flooded regions.

Table 2 Number of firms in non-affected and affected NUTSII-regions

	Number of firms	Percent
No-flood	67,507	49.21
Flood	69,677	50.79
Total	137,184	100.00

Table 3 Summary statistics of dependent variables

Variable	Treatment/ Period	Observations	Mean	SD	Min	Max
Total assets	0/0	49,016	11,297.190	129,259.900	0	18,576,594.330
	0/1	49,016	12,495.480	144,656.900	0	18,495,455.330
	1/0	47,307	11,101.120	121,798.200	0	14,058,479.330
	1/1	47,307	12,701.000	146,968.000	0	18,217,461.330
Employees	0/0	38,259	73.977	342.289	1	31,393.000
	0/1	38,259	77.440	280.141	1	13,121.670
	1/0	42,474	57.316	349.522	1	28,128.330
	1/1	42,474	65.359	505.564	1	82,815.500
Value added	0/0	43,034	3,556.295	28,354.60	$-1,096,014.000$	3,534,083.000
	0/1	43,034	3,596.777	31,834.330	$-97,977.000$	4,299,011.000
	1/0	44,519	3,398.755	30,611.560	$-84,494.330$	3,062,248.000
	1/1	44,519	3,608.459	44,336.870	$-418,642.000$	5,826,378.000

Notes: Total assets are measured in 1,000 US-Dollars

Table 4 Summary statistics of explanatory variables

Variable	Treatment/ Period	Observations	Mean	SD	Min	Max
Initial total assets	0/0	40,460	11, 593.070	123, 157.400	0	18,576,594.330
	1/0	38,946	12, 123.530	135, 847.800	0	15,131,069.000
Inital employment	0/0	27,058	82.700	327.712	1	14,565.000
	1/0	32,895	63.746	403.082	1	40,556.000
Age	0/0	26,719	18.290	16.561	0	302.000
	1/0	33,572	18.887	14.731	0	202.000
Shares of intangible assets	0/0	48,614	0.032	0.074	0	1
	0/1	48,614	0.033	0.072	0	1
	1/0	47,210	0.036	0.074	0	1
	1/1	47,210	0.037	0.073	0	0.911

Notes: Initial total assets are measured in 1,000 US-Dollars. The companies' age is calculated using 1999 as reference year

measured via value added of firms in affected and non-affected regions are higher in the post-flood period.

Table 4 reports the same data attributes for the explanatory variables. Companies in affected and non-affected regions also differ on average in initial values of total assets, employees and their level of intangible assets. The average age of companies in affected and non-affected regions is rather similar.

5 Results

As a first step, we focus on the effects of floods on capital accumulation and employment growth. Columns (5.1) and (5.2) of Table 5, depict the results estimating Eq. 1, columns (5.3) and (5.4) report regression results for Eq. 2. In order to choose the appropriate estimation model for total assets and employment growth we conduct Hausman specification tests. The results of the test statistics are reported at the bottom of Table 5 and indicate that the IV model should be favoured over the OLS estimates in the case of total assets. For employment, the OLS version outperforms the IV alternative. The following interpretation refers to these two preferred specifications.

The coefficient on initial total assets does not significantly differ from one and therefore supports the argument of Gibrat (1931) who proposes that the companies' growth is independent of their initial size. The effect of the initial level of employment is smaller than one indicating that companies with low initial levels of labour face higher growth than firms with a large initial stock. This observation corresponds to prevailing empirical findings in the firm size and firm growth literature (e.g., Fotopoulus and Louri 2004; Bloningen and Tomlin 2001) but contradicts Gibrat's law.

The companies' age reveals a significant and negative impact on total assets and employment changes, respectively, indicating that capital accumulation and employment growth of young firms are larger. This finding is in line with results in studies examining determinants of firm growth (e.g., Evans 1982; Sutton 1997). Also, a consistent picture is observable

Table 5 Estimates of flood event on total assets and employment growth

Variable	(5.1) OLS	(5.2) IV	(5.3) OLS	(5.4) IV
Initial total assets	0.907***(0.001)	1.010***(0.009)		
Initial employment			0.897***0.001)	0.978***(0.008)
Age	−0.095*** (0.002)	−0.150*** (0.005)	−0.057*** (0.002)	−0.099*** (0.005)
Shares of intangible assets (SIA)	−0.012*** (0.001)	0.000 (0.001)	−0.002** (0.001)	0.001 (0.001)
Time	0.107*** (0.004)	0.107*** (0.004)	0.165*** (0.004)	0.166*** (0.004)
Treatment (Flood)	−0.003 (0.004)	−0.004 (0.004)	−0.027*** (0.004)	−0.023*** (0.004)
Time * Treatment (DID)	0.090*** (0.010)	0.076*** (0.010)	0.088*** (0.009)	0.081*** (0.010)
Time * Treatment * SIA	0.019*** (0.002)	0.016*** (0.002)	0.013*** (0.002)	0.011*** (0.002)
Industry dummies	yes	yes	yes	yes
F-Stat	15.947***	7.382***	13.521***	8.718***
(df; df)	(102; 94,401)	(102; 94,401)	(102; 81,897)	(102; 81,897)
Country dummies	yes	yes	yes	yes
F-Stat	283.034***	285.510***	74.191***	63.076***
(df; df)	(3; 94,401)	(3; 94,401)	(3; 81,897)	(3; 81,897)
Sargan test[a]		2.416 (0.1201)		1.587 (0.2078)
Hausman test[a]	142.700** (0.027)		95.630 (0.8659)	
Adjusted R^2	0.898	0.890	0.886	0.880
Observations	94,514	94,514	82,010	82,010

Notes: Standard errors are given in parenthesis. The symbols *, ** and *** stand for 10%, 5% and 1% significance.

Included instruments: average firm size in NACE-classification industries, minimum efficient scale.
[a] P-Values are given in parenthesis

regarding the time effects. The time dummy captures the variation in physical capital stock and level of employment between the before and after flood period. Both equations reveal a positive influence on the growth of total assets and number of employees. The treatment dummy shows that input growth is, on average, lower in the treatment group but this difference is only significant for labour. We also control for industry and country specific effects by including industry and country dummies and find that they are jointly significant determinants of the dependent variables.

Previous long-run analyses have found a positive impact of disasters on capital as a whole. However, in the short run, the influence of floods and their side effects may differ for various types of assets. Some authors point at the differing resilience of assets regarding disasters (e.g., Hallegatte et al. 2007; Okuyama 2003; Skidmore and Toya 2002). We take this idea into account by introducing the structure of the firms' assets and distinguishing between intangible and tangible assets. While the latter is potentially exposed to flood the former is not.[16] Hence, a higher (lower) positive (negative) DID effect is expected the higher the share of intangible assets is. Consequently, the key parameters for our analysis are the share of intangible assets (SIA), the DID estimator (time*treatment) and the interaction with its asset share (time*treatment*SIA). The OLS-coefficient of SIA for labour in column (5.3) indicates that employment significantly decreases with an increasing share of intangible assets. The importance of the asset structure in determining the economic consequences of floods is strengthened by the coefficients of the DID variable and the interaction with the share of intangibles. As can be seen in Table 5 the corresponding parameters are significantly positive across all estimation models. The DID coefficient indicates that—ceteris paribus—companies in affected regions, on average, tend to possess higher total assets and employment growth after a flooding occurs than firms in non affected regions.

Effects on productivity may occur due to the consequences of floods on input factors which are passed on to the production process or, when a company was not directly hit, replaces some of the production shortfall from directly affected plants. We measure the productivity effects of a flooding via its impact on value added using OLS and IV estimation procedures and apply a Hausman test to define the accurate specification. The test statistics favour the IV over the OLS method. The corresponding estimates are reported in Table 6.

The coefficient on *SIA* in the IV model describes a positive influence of intangibles. The input coefficients show that on average the production process in our sample of firms tends to be more labour intensive. The sum of coefficients on total assets and employment is statistically different from one. In economic terms the difference is negligible which in turn indicates constant returns to scale. Differing from the asset and employment estimates, the time dummy reveals a negative impact and suggests—ceteris paribus—lower overall productivity in period $t+1$. The coefficient on the treatment dummy indicates a significant difference in the firms' productivity between companies in affected (flooded) and non affected regions: The average firm which is located in a flood region tends to be more productive than the average firm in the control group. In contrast to the input equations, the DID coefficient is no longer significant, however, the tendency is still positive.

In addition to the estimation of the average flood effect over the post-flood period, we are also interested in the dynamic evolution of the DID effect and, therefore, estimate our models for different points in time after the flood occurred.

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16 Our assumption regarding the vulnerability of intangibles refers to the stock of these assets as we focus in our analysis upon the influences of asset destruction on accumulation and future levels. However, if the 'production process' of intangibles (e.g., research activities) were examined one would have to consider that such activities might be interrupted by a severe event. This would of course also have an impact on the future stock of intangibles.

Table 6 Estimates of flood events on productivity

	Value added OLS	Value added IV
Total assets	0.432*** (0.001)	0.395*** (0.006)
Employment	0.562*** (0.002)	0.615*** (0.006)
Share of intangible assets (SIA)	−0.003*** (0.001)	0.016*** (0.002)
Time	−0.077*** (0.003)	−0.081*** (0.003)
Treatment (Flood)	0.094*** (0.003)	0.093*** (0.003)
Time * Treatment (DID)	0.005 (0.007)	0.028 (0.019)
Time * Treatment * SIA	0.008*** (0.001)	0.014*** (0.002)
Industry dummies	yes	yes
F-Stat	73.657***	58.665***
(df; df)	(102; 111,544)	(102; 111,544)
Country dummies	yes	
F-Stat	3731.867***	2905.104***
(df; df)	(3; 111,544)	(3; 111,544)
Sargan test[a]		1.180 (0.278)
Hausman testa	179.55*** (0.000)	
Adjusted R^2	0.922	0.920
Observations	111,657	111,657

Notes: Standard errors are given in parenthesis. The symbols ** and *** stand for 5% and 1% significance.
Included instruments: average region-industry inputs (total assets, employment, share of intangible assets, share of intangible assets*DID), average region-industry material costs per employee. [a] P-Values are given in parenthesis

Table 7 Dynamic evolution of the flood effect

Variable	Total assets	Employment	Value added
	IV	OLS	IV
DID_t	0.044*** (0.010)	0.050*** (0.010)	0.022 (0.023)
DID_{t+1}	0.054*** (0.011)	0.079*** (0.011)	0.103*** (0.021)
DID_{t+2}	0.091*** (0.011)	0.106*** (0.011)	0.062*** (0.021)

Notes: Standard errors are given in parenthesis. The symbols *, ** and *** stand for 10%, 5% and 1% significance. The effects are only reported for the preferred models

Table 7 shows the effects of the flood event on input factors and on productivity at different points in time after the flood. For example, DID_t captures the average effect of the flood at the end of the year 2000 while DID_{t+1} depicts the average impact of the flood until the end of 2001, and so on.[17] The results indicate that the immediate effect of the flood is less pronounced than in the years that follow. Moreover, the effects tend to increase over time and are highest at the end of our observational period indicating that in the long-run one might observe a positive effect on input factors as well as a positive effect on productivity, which would be in line with previous findings.

We check the sensitivity of our baseline estimation results regarding the flood effect on input factors and the effect on productivity by incorporating two different ideas. First, we include all firms in regions in which a flood in 2000 occurred. This approach enables us to compare whether multiple-affected firms systematically differ from firms which are only affected by a single flood event. While the estimation results with respect to the input factors are hardly affected, the DID coefficient in column (2) of Table 10 becomes highly significant indicating a positive flood effect regarding the firms' average productivity. In a second step, we also include indicators for other natural hazards as additional controls. Storms are the

[17] For this reason the average of the DID effects at different points in time is supposed to be comparable to the average effects in the baseline estimation.

Table 8 Overall (marginal) effects of a flood for different shares of intangible assets (SIA)

Variable	(8.1) Total assets	(8.2) Employment	(8.3) Value added
Mean	0.005 (0.810)	0.030*** (370.600)	−0.035*** (70.760)
10th Percentile	−0.032*** (19.130)	−0.001 (0.002)	−0.068*** (39.890)
20th Percentile	−0.019*** (8.190)	0.010* (2.920)	−0.056*** (53.510)
1st Quartile	−0.014** (4.700)	0.014** (6.220)	−0.053*** (61.050)
30th Percentile	−0.009 (2.220)	0.018*** (10.380)	−0.048*** (68.690)
40th Percentile	−0.001 (0.020)	0.025*** (20.810)	−0.041*** (79.000)
Median	0.007 (1.330)	0.031*** (33.110)	−0.034*** (65.820)
60th Percentile	0.014** (5.630)	0.037*** (45.770)	−0.027*** (34.780)
70th Percentile	0.022*** (12.46)	0.044*** (58.210)	−0.020*** (12.550)
3rd Quartile	0.026*** (16.68)	0.047*** (64.130)	−0.017** (6.580)
80th Percentile	0.030*** (21.220)	0.050*** (69.580)	−0.013* (3.050)
90th Percentile	0.041*** (32.240)	0.059*** (79.850)	−0.003 (0.120)
Observations[a]	25,720	23,695	31,494

Notes: Values of F-Statistic from non-linear Wald test given in parenthesis. The symbols ** and *** stand for 5% and 1% significance.
[a] Number of firms which are located in flood regions

second relevant hazardous event that affects the countries in our sample. We include a storm dummy which equals 1 when a storm occurred and 0 otherwise. The results of this alternative specification do not differ much from the original version. The corresponding tables are presented in the appendix.

The overall short-run flood effect is given by the first derivative with respect to DID. The marginal effects of a major flood event for total assets, employment and productivity are reported in Table 8.[18] We report the marginal effects for various levels of SIA in order to highlight the importance of controlling for different levels of risk exposure of assets when analysing the short-run impacts of disasters. These estimates clarify that the overall increase in capital growth does not hold for all companies. Rather, firms with high tangible assets are negatively affected by floods which is expressed as a decrease in total assets. From the 60^{th} percentile of intangibles upwards a significantly positive flood effect is observable. A monotonic increase in growth is recognisable for employment. The higher the amount of intangible assets of companies, the more pronounced is the employment growth effect in the post-flood-period. Column (8.3) of Table 8 shows the overall effects on productivity for different shares of intangible assets. Our short-run results regarding the firms' productivity reveal that the (partly) positive effects on factor inputs do not lead to higher productivity. In fact, the occurrence of floods significantly reduces the efficiency of companies in affected regions but the decline is less pronounced for companies with large intangible values.

When one considers the findings in previous long run analyses regarding the impact of natural disasters on firm performance our results may be striking. Long-run analyses argue that companies which are forced to update their (old) capital by new equipments will face higher growth and productivity in the long run. For comparison, we find evidence that capital accumulation, employment and productivity is higher for those firms which have less capital at risk (higher intangible assets) and thus face lower pressure to replace assets. These seemingly contrary results can be explained by our focus on a short-run perspective. As the simulations in Murlidharan (2003) show, replacing assets needs some time and the changes in capital during this recovery period are lower the more severe the loss ratio. Our empirical

[18] The calculations only refer to companies located in affected regions after the flooding occurred. The parameter estimates of the preferred models are applied.

estimates are in line with these arguments: In the short run, total assets, employment and productivity in companies with high intangibles (=lower loss ratio) is above the values in companies with more capital at risk. One reason for this ‘short-run-boost’ observable for firms with high intangibles may be that such companies can focus on production processes (which may be even more pronounced if they compensate output losses of flood affected firms). Whereas establishments with high loss ratios have to channel their efforts into achieving the pre-disaster status.

Our results indicate that a major flood event reduces productivity of firms located in the affected region. In other words, firms were not able to transfer the positive effect on input factors into higher productivity. This decrease in productivity is most pronounced for firms which do not use intangible assets in their production process.[19]

6 Conclusions and Discussion

In economic terms, natural disasters can initiate a sudden, exogenous shock for the firms’ production factors. The corresponding consequences do not only evolve through the physical destruction per se but may be accompanied by effects on labour and productivity.

The analysis in this paper focuses on short-run effects of disasters on firm behaviour. In particular, we examine the average consequences of floods on the firms’ factor endowment and productivity and differentiate between flood-resistant and flood-sensitive endowments. Using a difference-in-difference (DID) approach we distinguish between affected and non-affected regions and two time periods—before and after flooding—to analyse the average change in total assets, employment and productivity induced by a flooding. We also find evidence that some part of the capital is less vulnerable to disasters. However, the short-run effects on productivity are negative. Our results let us assume that short-run and long-run analyses may come to different conclusions regarding the impact of disasters on firm performance.

In particular, the estimates provide evidence that post-flooding employment growth for companies in flooding regions is higher. This positive impact increases with higher shares of intangible assets. The overall effect of a major flood on physical capital accumulation depends on the share of intangible assets in the production process. After a flood, physical capital accumulation increases for companies with a low fraction of tangible assets. Conversely, the post-flooding effect on productivity in the treatment group is always negative. The natural catastrophe may induce investment activities in production factors that go beyond the sole replacement of disaster losses and result in a less productive factor composition. The idea of an increase in total factor productivity could therefore hold in the long-run, but this increase seems to be preceded by a decrease in factor productivity in the short-run. However, this negative impact of floods on productivity slows down with increasing shares of intangible assets.

We interpret the findings regarding the impact of floods on total assets accumulation, employment growth and productivity as evidence that firms with high intangibles are less vulnerable with regard to flood impacts. The marginal effects further highlight that positive capital and employment effects do not necessarily lead to higher productivity in the short-run.

[19] The same relation may also hold for the crucial decision criterion of profit maximization: Although affected firms face positive capital and employment effects the profit may be lower compared to pre-flood periods. While companies affected by disasters are forced to replace and/or restructure their factor inputs to continue their business even if these activities reduce profits, non-affected firms are expected to change their input composition only if this leads to higher profits.

Furthermore, our results provide evidence that at least in the short-run, companies are not able to transform increased factor inputs into higher productivity. Long-run analysis needs to account for the duration of the adjustment process. Considering that climate change induced natural disasters may occur more frequently and intensively, the challenge will be to minimize the time span of searching for the optimal factor composition. If industries fail to apply appropriate strategies, adverse consequences of natural hazards due to climate change will intensify human suffering.

The examination of the dynamic economic effects of several temporally correlated exogenous flood events and analysing their impact on social welfare might be an interesting question for further research.

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Appendix

Robustness Checks

Table 9 Estimates of flood event on total assets and employment growth, including all firms in regions with a 2000-flooding

Variable	(1) OLS	(2) IV	(3) OLS	(4) IV
Initial total assets	0.907*** (0.001)	1.019***(0.008)		
Initial employment			0.901*** (0.001)	0.984*** (0.008)
Age	−0.093*** (0.002)	−0.154*** (0.005)	−0.057***(0.002)	−0.100*** (0.005)
Share of intangible assets (SIA)	−0.012*** (0.001)	0.000(0.001)	−0.002*** (0.001)	0.001 (0.001)
Time	0.107*** (0.004)	0.107*** (0.004)	0.158***(0.004)	0.158*** (0.004)
Treatment (Flood)	−0.009** (0.004)	−0.007* (0.004)	−0.022*** (0.004)	−0.018** (0.004)
Time * Treatment (DID)	0.095*** (0.009)	0.082*** (0.009)	0.084*** (0.009)	0.078*** (0.009)
Time * Treatment * SIA	0.018*** (0.002)	0.015*** (0.002)	0.013*** (0.002)	0.011*** (0.002)
Industry dummies	yes	yes	yes	yes
F-Stat	18.107***	8.127***	13.335***	8.225***
(df; df)	(102; 111,047)	(102; 111,047)	(102; 93,949)	(102; 93,949)
Country dummies	yes	yes	yes	yes
F-Stat	274.556***	256.864***	59.370***	57.927***
(df; df)	(5; 111,047)	(5; 111,047)	(5; 93,949)	(5; 93,949)
Sargan test[a]		2.925 (0.087)		0.130 (0.719)
Hausman test[a]	183.47*** (0.000)		109.580 (0.600)	
Adjusted R^2	0.899	0.889	0.889	0.883
Observations	111,162	111,162	94,064	94,064

Notes: Standard errors are given in parenthesis. The symbols *, ** and *** stand for 10%, 5% and 1% significance.
Included instruments: average firm size in NACE-classification industries, minimum efficient scale. [a] P-Values are given in parenthesis

Table 10 Estimates of flood events on productivity, including all firms in regions with a 2,000-flooding

	(1) OLS	(2) IV
Total assets	0.434*** (0.001)	0.402*** (0.005)
Employment	0.561*** (0.002)	0.614*** (0.006)
Share of int assets (SIA)	−0.003*** (0.001)	0.016*** (0.002)
Time	−0.076*** (0.003)	−0.081***(0.003)
Treatment (Flood)	0.074*** (0.003)	0.072*** (0.003)
Time * Treatment (DID)	0.014** (0.006)	0.045*** (0.017)
Time * Treatment * SIA	0.008*** (0.001)	0.015*** (0.004)
Industry dummies	yes	yes
F-Stat	88.212***	72.087***
(df; df)	(102; 125,940)	(102; 125,940)
Country dummies	yes	
F-Stat	3493.817***	2794.822***
(df; df)[b]	(4; 125,940)	(4; 125,940)
Sargan test[a]		0.272 (0.602)
Hausman test[a]	231.25*** (0.000)	
Adjusted R^2	0.923	0.921
Observations	126,054	126,054

Notes: Standard errors are given in parenthesis. The symbols ** and *** stand for 5% and 1% significance. Included instruments: average region-industry inputs (total assets, employment, share of intangible assets, share of intangible assets* DID), average region-industry material costs per employee

[a] P-Values are given in parenthesis

[b] There is no information available on value added of firms located in Greece

Table 11 Estimates of flood events on total assets and employment growth, controlling for storm events

Variable	(1) OLS	(2) IV	(3) OLS	(4) IV
Initial total assets	0.908*** (0.001)	1.008*** (0.009)		
Initial employment			0.896*** (0.001)	0.977*** (0.008)
Age	−0.097*** (0.002)	−0.150*** (0.005)	−0.057*** (0.002)	−0.098*** (0.005)
Shares of intangible assets (SIA)	−0.012*** (0.001)	0.000 (0.001)	−0.002** (0.001)	0.001 (0.001)
Time	0.106*** (0.004)	0.107*** (0.004)	0.166*** (0.004)	0.166*** (0.004)
Treatment (Flood)	−0.003 (0.004)	−0.005 (0.004)	−0.026*** (0.004)	−0.023*** (0.004)
Time * Treatment (DID)	0.092*** (0.010)	0.077*** (0.010)	0.088*** (0.009)	0.081*** (0.010)
Time * Treatment * SIA	0.019*** (0.002)	0.016*** (0.002)	0.013*** (0.002)	0.012*** (0.002)
Storm	−0.004 (0.005)	0.004 (0.006)	−0.006 (0.005)	−0.005 (0.005)
Industry dummies	yes	yes	yes	yes
F-Stat	15.955***	7.463***	13.617***	8.742***
(df; df)	(102; 93,840)	(102; 93,840)	(102; 81,356)	(102; 81,356)
Country dummies	yes	yes	yes	yes
F-Stat	199.249***	187.420***	71.644***	60.574***
(df; df)	(3; 93,840)	(3; 93,840)	(3; 81,356)	(3; 81,356)
Sargan Test[a]		3.248* (0.07)		1.726 (0.189)
Hausman Test[a]	137.530* (0.058)		93.210 (0.913)	
Adjusted R^2	0.899	0.879	0.885	0.879
Observations	93,954	93,954	81,470	81,470

Notes: Standard errors are given in parenthesis. The symbols *, ** and *** stand for 10%, 5% and 1% significance.

Included instruments: average firm size in NACE-classification industries, minimum efficient scale

[a] P-Values are given in parenthesis

Table 12 Estimates of flood events on productivity, controlling for storm events

	(1) OLS	(2) IV
Total Assets	0.432*** (0.001)	0.397*** (0.006)
Employment	0.562*** (0.002)	0.613*** (0.006)
Shares of intangible assets (SIA)	−0.003*** (0.001)	0.016*** (0.002)
Time	−0.077*** (0.003)	−0.082*** (0.003)
Treatment (Flood)	0.092*** (0.003)	0.092*** (0.003)
Time * Treatment (DID)	0.003 (0.007)	0.021 (0.019)
Time * Treatment * SIA	0.008*** (0.001)	0.012*** (0.004)
Storm	0.022*** (0.004)	0.013*** (0.004)
Industry dummies	yes	yes
F-Stat	73.569***	58.664***
(df; df)	(102; 111,034)	(102; 111,034)
Country dummies	yes	
F-Stat	3286.687***	2483.059***
(df; df)	(3; 111,034)	(3; 111,034)
Sargan test[a]		0.904 (0.342)
Hausman test[a]	163.780*** (0.001)	
Adjusted R^2	0.922	0.920
Observations	111,148	111,148

Notes: Standard errors are given in parenthesis. The symbol *** stands for 1% significance
Included instruments: average region-industry inputs (total assets, employment, share of intangible assets, share of intangible assets* DID), average region-industry material costs per employee
[a] P-Values are given in parenthesis

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