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Okubo, Toshihiro; Strobl, Eric

DOI:
10.1111/jors.12523

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Document Version
Peer reviewed version

Citation for published version (Harvard):
Okubo, T & Strobl, E 2021, 'Natural disasters, firm survival, and growth: evidence from the Ise Bay Typhoon, Japan', *Journal of Regional Science*, vol. 61, no. 5, pp. 944-970. https://doi.org/10.1111/jors.12523

Natural Disasters, Firm Survival and Growth: Evidence from the Ise Bay Typhoon, Japan

Toshihiro Okubo (Keio University)
Eric Strobl (University of Bern)[1]

Abstract

This paper investigates the damage impact of the 1959 Ise Bay Typhoonon firm survival and survivor performance in Nagoya City, Japan. We combine firm-level data with a local damage proxy storm surge-induced flooding. We find that firms in retail and wholesale were less and those in manufacturing more likely to survive after being flooding. There was some evidence of spillover effects from nearby regions on firm exit. Surviving firm performance was heterogeneous across sectors in that some (manufacturing and construction) upgraded and others (retail and wholesale) their capital. Indirect impacts from nearby regions were both positive and negative, contingent on the sector of operation.

Keywords: Typhoon, Flood, Firm survival, Firm growth, Nagoya city

JEL classification: Q54, R10, R12, R14, D22, L25

Conflict of Interest Statement: The authors certify that they have NO affi liations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

[1] Okubo: Faculty of economics, Keio university, 2-15-45 Mita, Minato-ku Tokyo, Japan. okubo@econ.keio.ac.jp, Strobl: Department of Economics, University of Bern, Switzerland.

1. Introduction

Supertyphoon[1] Vera, also known as the Ise Bay Typhoon, made landfall in Japan on the 26th of September 1959. The storm reached maximum wind levels of up to 258 km/hr resulting in storm surges of nearly 4 m. It is arguably the most infamous tropical cyclone in the history of Japan. As a matter of fact, it was the most destructive storm in the modern Japanese period, causing monetary damages to the equivalent of US$2.3 billion dollars today, including 834,000 damaged or destroyed buildings and nearly 5,100 fatalities in the Ise Bay area (JWF, 2005). In addition, the Japanese government passed the cornerstone of today's disaster-risk reduction legislation in the aftermath of the storm, i.e., the Disaster Countermeasures Basic Act, which outlined processes for co-ordinated disaster prevention and management at the highest levels of government (RMS, 2009). However, while the importance in terms of the direct losses and the consequent political implications of the supertyphoon are well-known, there is essentially no quantitative evidence in terms of what these losses meant for the locally affected economies, which limits the local post-disaster management lessons that can be learnt from the event. In this paper, we explicitly investigate this aspect by examining how firms located in Nagoya City, the most-damaged area in the Ise Bay region,[2] were affected by the supertyphoon.

An important historical commercial and industrial centre of Japan at the time, the port city of Nagoya was subject to extensive water inundation when its existing flood defences broke during the storm, leaving some areas flooded for up to 4 months (JWF, 2005). Nearly 50,000 structures in Nagoya City were fully or partially collapsed and 70,000 buildings were severely damaged by the flood waters. Moreover, materials from industrial facilities were washed away and large amounts of floating timber blocked roadways and destroyed more buildings. While this extensive damage is likely to have had an immediate negative impact on local business activity, the extent of the indirect impact on the city's post-event performance is unclear. Other studies of the impact of flooding on firms did not shed light on this aspect. More precisely, while there is a sizeable and growing literature on the impact of flooding on national or regional economic performance (e.g., Husby et al., 2014; Lima and Barbosa, 2019; de Oliveira 2019; Noy et al. 2019),[3] studies on the impact at firm level are rather limited. For example, Leiter et al. (2009) examine the impact of floods on European firm performance and find that those located in flooded areas experience stronger growth in both employment and capital accumulation, but a negative impact on productivity. By contrast, Coelli and Manasse (2014) find that enterprises damaged by floods have higher value added two years after the event. In terms of the probability of shutting down for damaged firms after Hurricane Katrina, Craioveanu and Terrell (2016) show that they were less likely to survive. This result is echoed by Basker and Miranda (2018), who find that, conditional on survival after Hurricane Katrina, larger and more-productive businesses hired more workers than smaller and less-productive ones. Apart from flooding, there are several studies on the effect of other types of natural disasters. Although the dynamics of other natural disasters are different, basic mechanisms that explain the interaction between natural disasters and economic performance are arguably similar. More specifically, the negative effects on economic activity often tend to quickly recover to pre-disaster level (Elliott et al. 2015; Husby et al. 2014; Tanaka, 2015), while other studies have found that large natural disasters did not affect long-run economic growth, although political or institutional biases exist (Barone and Mocetti, 2014; Cavallo et al. 2013).

In this paper, we build on the existing research by investigating the possibly heterogeneous impact of the Ise Bay Typhoon on firms of Nagoya City on their survival as well as the effect on sales, employment, labour productivity, and capital for survivors. Our contribution to the literature is on several fronts. First, we examine the issue of the impact of natural disasters in a historical context where the central government did not yet have well-co-ordinated systematic plans and laws for natural disasters and there was no automatic legal framework for distributing governmental post-disaster aid to firms nor any non-government/non-profit organizations to help recovery. In this setting, one has arguably much greater insight into the impact of natural disaster damage on firm behaviour. Secondly, we use unique historical firm-level data as well as a flood inundation map from a time period when there is generally almost no availability of high-quality firm-level data or damage maps. Finally, our study highlights the heterogeneous impact of damage across sectors using firm-level data.

To conduct our analysis of the impact of flooding due to the Ise Bay Typhon in Nagoya City we digitalize a unique data set of firms and geo-reference a detailed map of the location and duration of storm surge flooding. More specifically, for the former we use printed volumes that exhaustively cover all firms with capital assets above 1 million yen in the city, including information on their location and various firm performance indications (e.g., sales, employees, capital assets and founding year) immediately before and several years after the typhoon. This provides us with a unique data set that allows us to examine how flooding after the typhoon affected survival and short- and medium-term post-survival performance, both directly and through spatial spillovers.

In our analysis we specifically focus on possible sectoral heterogeneity of the impact of storm surge on firm behaviour after the Ise Bay Typhoon. This may be important because firms in certain sectors are more reliant on capital stock, which is likely to be damaged, than others, such as manufacturing versus service firms (Leiter et al., 2009). Firms in sector such as construction may actually benefit from damages as demand for their product increases (Strobl and Walsh, 2009). Finally, they may have been affected by damages through input-output linkages that could differ across sectors (Rose and Wei, 2013). Studies indicating the importance of taking account of sectoral heterogeneity in estimating the economic impact of natural disasters include Loayza et al (2012), Panwar and Sen (2019), and Groen et al (2020), although not using firm level data.

Our empirical strategy to investigate the impact of storm surge flooding on firm performance is to estimate a spatial Difference-in-Differences (DID) model in the spirit of Delgado and Florax (2015), but extend this to a continuous treatment context. Causal identification of this approach is based on the assumption that local flooding incidences are as good as random draws from the local (expected) probability distributions of possible flooding, and that any other factors, such as infrastructure investments prior to the storm that may cause firms to perform differently and may coincide with flooding, can be captured by time trends at a higher spatial level than our flood data. For the firm survival results to have causal interpretation we need to make the additional stronger assumption that expected probability distributions of storm surge vary only at the Ward level when firms or governments make their location decisions.

Our findings show that flooding due to the storm surge from the Ise Bay Typhoon increased the probability of firms shutting down only in some sectors, while in other industries it either had no effect, or reduced firm exit. We also find considerable firm heterogeneity of the impact of storm surge on ex-post firm performance, again sometimes impeding, sometimes boosting, and sometimes having no average effect. Moreover, the nature of impact depended on the time horizon. More generally, our study highlights the importance of sectoral differences in responding to damages from tropical storm flooding.

The remainder of the paper is organized as follows. In the following section, we describe the background context of the Nagoya City and Ise Bay Typhoon. In Section 3, we present our data and provide summary statistics. Section 4 describes our empirical strategy, while Section 5 contains our econometric analysis. Our findings are discussed in the historical context in Section 6. The final section provides some concluding remarks.

2. Background

2.1 Nagoya City

With the third largest population in Japan (1.3 million in 1955 and currently 2.3 million), Nagoya City is today a central component of the country's big industrial bloc, but had been a commercial and manufacturing centre already for several hundred years. As an internationally important port city, Nagoya has historically played a crucial role in Japan's production of textiles, pottery and machinery industries. In considering its historical importance, it is important to emphasize that the city's initiation into modern urban planning was earlier than for other cities in Japan (Numajiri, 2002). The municipality's urban planning split the city into zones for commercial, manufacturing, and residential areas. The commercial area was designed as the eastern area of the Nagoya Central Railway Station, which has been the site of a cluster of commercial shops and markets since the 17th century. At the time, the manufacturing zone was designed from the northern to the southern areas by attracting large manufacturing firms. This created a manufacturing corridor from the northern area near Nagoya Central Railway Station to the southern area through to Nagoya Port in Ise Bay. The Nakagawa Canal was constructed in 1930 along this corridor to connect the Nagoya City centre to the port and facilitate transportation from inland areas to the port. As such, Nagoya City intended to create a cluster of manufacturing firms along the canal (Numajiri, 1995, 2002).[4]

Nagoya City's overall urban planning strategy managed to develop a number of industries successfully. In the 1920s and 1930s, textile and machine industries increased production and became important exporting sectors. In the late 1930s, many military related firms, such as aircraft, also became concentrated in Nagoya. After WWII, many manufacturing firms in textiles, pottery, and the sewing machine industries started operating in the manufacturing area, which contributed to boosting its economic. New industries such as motorcycle manufacturing emerged in the 1950s. One should note that even after the destruction caused by the Ise Bay Typhoon, Nagoya City continued to be a location for major industrial production in Japan (Nagoya City, 2012).

It is important to point out that Nagoya City, which is built on coastal low-lying land, has a long history of flooding. For example, a large typhoon hit the city on the 15th of August 1907 and 22 people died, while 4,827 ha of agricultural fields were inundated. On the 22nd of September 1912, another large typhoon with a high tide reaching 4.6 m resulted in 155 deaths and 9258 buildings being inundated. Moreover, several artificial islands in Nagoya Port were submerged and the timber in their yards was released to the sea but flowed inland with the high tide and hit a large number of buildings and infrastructure, causing more serious damage. In spite of this, the demand for timber increased and the timber export industry grew substantially in Nagoya Port, which led to the establishment of many more timber yards in the port and rivers (Yamaguchi, 2015). This increased the risk of serious damage by timbers in typhoons and high tides. On the 25th of September 1921, another typhoon struck and broke several areas again. Unsurprisingly, infrastructure investment for disaster prevention had been a big issue in Nagoya City long before the Ise Bay Typhoon made landfall (Yamaguchi, 2017).

2.2 The Ise Bay Typhoon and its Impact

Supertyphoon Vera, also called the Ise Bay Typhoon, was recorded as the largest storm in modern Japanese history. The supertyphoon hit the Ise Bay area in late September 1959, making landfall on the 26th September and passing through the Ise Bay region and the southern coast of mainland Japan, while gaining strength

(930 mb pressure and more than 40 m/s of maximum wind speed) and causing catastrophic damage to the area. Estimates suggest that 5,098 people were killed or missing, 38,921 people were injured, and 1.5 million people became homeless in the Ise Bay area. As a result the strong storm also destroyed coastal seawalls and thousands of buildings and caused widespread flooding in the Nagoya area. The total damage has been estimated to have been around 260 million USD (currently equivalent to nearly 2.3 billion USD) (Central Disaster Management Council, 2008). Table 1 reports some basic statistics on the damages in Nagoya City (located in the centre of the Ise Bay area), e.g., 1,900 people were dead or missing, 40,000 people were injured, and 120,000 buildings were damaged in Nagoya City.

PLACE TABLE 1 HERE

Importantly, the supertyphoon caused a high tide, which flooded Nagoya City, i.e., the inmost bay of the Ise Bay region. The high tide first happened in the seaside of southern Nagoya City and then flowed backwards up rivers and canals and over collapsed levees, which further expanded the flooded area of the inland city. In the lowland area, the high tide caused large-scale and long-run inundation. Moreover, since Nagoya Port was used by many timber yards, more than 200 thousand tons of timber escaped from the yards into the inland area during the supertyphoon. These timbers damaged many buildings and killed or injured a number of people (Tani, 1960).

In terms of damaged local industries, the damage and recovery experience appears to have substantially differed across these. According to Tani (1960), 31% of manufacturing factories in Nagoya City were damaged, where the damage in raw materials, final products, intermediate products, buildings, and capital amounted to 5.8, 2.3, 1.6, 11.1, and 13.8 billion yen, respectively. Nevertheless, manufacturing firms, in particular large ones, are believed to have experienced relatively little direct damage. For example, some firms located on reclaimed lands close to the sea survived by having artificially raised their buildings to above the ground level before the supertyphoon, although this did not prevent some machines from being flooded by the high tide (Central Disaster Management Council, 2008).

Considering commerce in Nagoya City, 34% of commercial shops/retailers were damaged and the loss of products, facilities, and capital/machines amounted to 5.8, 1.6, and 1.8 billion yen, respectively (Tani, 1960). Still, the commercial markets never panicked and the prices of daily products never surged while transactions of these daily products in the market continued nearly as before (Nagoya City, 2012). Even if the shops in the shopping areas were inundated and collapsed, their business continued, and daily products were aggressively sold in front of the collapsed shops. Some shops provided clothes muddied by the flood for free (*Chubu Nihon Newspaper*, 28th of September and 5th of October 1959). Additionally, many Nagoya City department stores recovered quickly and held bargain sales in temporary buildings. At the end of 1959, commercial sales increased by more than 15% compared with the same period in the previous year (*Chubu Nihon Newspaper*, 27 December 1959).

3. Data and Summary Statistics

3.1 Flood Damage Data

To proxy local damages within Nagoya City due to storm surge after the supertyphoon, we use a map of the number of days flooded at the Chomé level, which is the minimum level of spatial delineation in Japan. This is taken from the printed version of *Shinshu Nagoya-shi Shi*, Shiryo-hen (Gendai) (*Book Volumes on Nagoya City History*, data appendix [post-war period]) (Nagoya City, 2012). We geo-referenced this map to create a geographical shapefile (Figure 2). As can be seen, there is considerable heterogeneity of the inundation days across Chomés, ranging from 0 to up to 60 days. Importantly, using the number of days inundated allows us not only to capture whether a firm was affected by flooding, but also how long the flooding affected the firm. This flooding variable (FLOOD) constitutes our main variable of interest. We also use it to generate a measure of floods in neighboring Chomés WFLOOD, defined inverted distance average number of flooding days in other Chomés.

3.2 Firm-level Data

Generally, firm-level data from the 1950s and 1960s is rare for most countries. Our source for firm-level data for Japan are the *Teikoku Ginko Kaisha Youroku* volumes, which were published by Teikoku Koushinjo Co., Ltd. Although the data were published annually from the 1910s to 1940s, the company stopped publication during the war period and restarted in 1951, covering a few prefectures. The data cover all companies with capital assets over 1 million yen as well as all banks and credit co-operatives, i.e., not only manufacturing industries, but also construction, services, including wholesale and retail sectors, among other miscellaneous industries (e.g., public utilities and transportation services). The data include information on a firm's location, year of founding, employees, sales, capital assets, and sector of production. Sales are defined as annual sales from revenue per firm (unit: 10 million yen). Capital assets per firm (unit: 10 million yen) are not tangible assets but capital funds. Employment is the number of regular employees. Unfortunately, we do not have city, Ward, or Chomé level price data. Hence we leave monetary variables at their nominal level, so that any common price changes are controlled for by time dummies and Ward specific time trends in the econometric analysis.

We focus on companies located in Nagoya City, which was the area most seriously damaged by the Ise Bay Typhoon.[5] Since the data before/after the Ise Bay Typhoon are available for only a few years, considering data quality, we collated the data for the years 1958 (the first year available to us) as pre-disaster period and 1960 to 1963 as post-disaster periods (for 1959 there was no data available), where information on firms was collected from September to November of those years. We thus have snapshots of the populations of firms (with capital assets over 1 million yen) in one year immediately prior and four years immediately after the supertyphoon. Our analysis is thus limited to capturing only any short- and medium-, but not the long-term impact of the supertyphoon.

3.3 Summary Statistics

Our sample contains information on a total of 2,093 firms. Table 2 provides the summary statistics for all our variables of these, as a total, for the year prior to the typhoon, and for all four years after the typhoon. As firm level variables, we use annual sales as a proxy of firm size (SALE), capital asset (CAPITAL), the number of total regular employees (EMP), sales per employee as proxy of labor productivity (SALE_EMP), and firm age (AGE). Chomé level variables the average flood says (FLOODD) and the inverse distance weighted average of flood days in all other Chomés (WFLOODD). As can be seen in the left panel of Table 2, there is considerable variation across all characteristics. In particular, firm size ranged from between 2 to over 18,000 employees and between just having started operation and having operated for 68 years. Our firm performance measures also differ widely. Importantly, the number of days flooded due to the super typhoon ranged from being non-affected to 25 days, where the standard deviation of 3.34 suggests considerable variation around the mean. Comparing the firm performance variables before and after the typhoon (middle and right panels of Table 2), one discovers that on average sales, capital, and employment are larger for surviving firms, while labour productivity has slightly fallen.

PLACE TABLE 2 HERE

We show the geographic distribution of the number of firms and flood days in Figures 1, and 2, respectively. Accordingly, there is an uneven spread of firms across the city, with most firms located within the geographical centre (in the east of Nagoya Central Railway Station). These are mainly commercial firms, whereas the manufacturing zone spreads from the southern to northern Nagoya City, as mentioned in the previous section. However, there is large variation in the number of enterprises even within the Chomés that contain firms, ranging from 1 to 103. As can also be seen, the geographical distribution of days flooded is also fairly spatially heterogeneous. One should note that 66% of the firms in our sample were in Chomés that experienced at least some flooding.

PLACE FIGURES 1 AND 2 HERE

4. Econometric Methodology

Our main goal is to investigate how the flooding due to storm surge caused by the Ise Bay Typhoon impacted firms' probability of survival and the performance of survivors. As mentioned above, Chomé is a small district and the smallest geographical administrative area in Japan. In this regard, we allow for a direct effect of the typhoon via a firm's location it its own Chomé as well as spatial (weighted) spillovers from other locations (Chomés). The latter may be justified on the grounds that Chomé's are unlikely to be isolated input markets, where firms may procure material and labour inputs from other geographical areas and thus shocks to these may propagate through space. Similarly, firms may also spatially compete on product markets with each other across Chomés, so that shocks to production may affect nearby regions. Finally, infrastructure that firms rely on may be affected by both local and geographically distant destruction.

4.1 Firm Survival

To determine the role of storm surge and wind damages arising from Ise Bay Typhoon we estimate the hazard of a firm *i* closing down at time *t*, i.e., $h_i(t)$, via a Cox Proportional Hazard Model:

$$h_i(t) = h_0(t)\exp(\beta_0+\beta_1 FLOODD_i+\beta_2 \mathit{W}FLOODD_i+\beta_3 SALE_{it-1} + \beta_3 EMP_{it-1} + \beta_3 CAPITAL_{it-1} + \beta_6 AGE_{it-1}+ \lambda_t + \gamma_j + \varphi_i + trend_{jt} + \varepsilon_{it}) \quad (1)$$

where FLOODD is the number of days that the Chomé that firm *i* is located in was flooded, *W*FLOODD is the inverse distance weighted average of flood days that other Chomés experienced, SALE is the log of total annual sales, EMP the log of total employment, CAPITAL the log of value of capital assets, AGE is the age of the firm, and ε is an error term. We also include a set of sector dummies (φ), year dummies (λ), ward specific dummies (γ), and ward specific time trends (trend). One should note that Wards are the administrative spatial units immediately above Chomés, and that there are 12 wards in our region of analysis. The ward specific time trends (trend) are intended to capture any trend in firm performance that differs across Wards and potentially is correlated with flooding due to the storm, while the ward dummies captures all unspecified time invariant differences in Wards.

The Cox Proportional is semi-parametric in that the baseline hazard h_0 is estimated non-parametrically and only depends on time *t*, but the risk factors are estimated parametrically, where as usual we assume that the parametric function takes an exponential form. The hazard of firm *i* closing down is thus multiplicatively proportional to the baseline hazard h_0. One should note that one can think of our variables of interest – FLOODD and *W*FLOODD– as different, continuous, treatment variables, where their estimated coefficients, conditional on these being exogenous, together capture the average treatment effects.[6] Given that these are measured at the Chomé level, we appropriately cluster the standard errors at this level (Bertrand, et. al, 2004).[7] Including WFLOOD allows us to investigate whether there are spatial correlation effects in terms of inundation in neighboring Chomés or spatial responses of firm survival to flooding. This could, for instance, occur if firms source inputs from neighboring areas, and/or firms in neighboring areas act as competitors in the output market. Not controlling for such spatial interactions could lead to omitted variable bias; see Delgado and Florax (2015).

Causal identification of the impact of FLOOD and WFLOOD on firm survival in (1) requires the assumption that there were no other Chomé level factors that may have affected the probability of survival and are correlated with the number of flooding days of the Chomé that a firm is located in, after controlling for time invariant and trend differences a the higher spatial (Ward) level. This would be violated, for instance, if more productive firms, once they choose in what Ward they will locate and take account of (trending) changes in that Ward, then decide on which Chomé within that Ward to operate, and these features are correlated with the likelihood of that, or a neighboring, Chomé being inundated after a Typhoon and, importantly, also affect firm survival.

In view of this possibility one may want to note that neither Chomés nor Wards have ward have a separate government body, i.e. no parliament, independent budgets/expenses, nor tax structures, but rather that all public decisions are taken at the city level. Thus, for example, infrastructure project is based on city and prefecture rather than ward level and chome level considerations.[8]

4.2 Firm Performance

In order to estimate the role of flood and wind exposure damage on firm performance we run the following linear model:

$$\log(Y_{it}) = \beta_0+\beta_1 FLOODD_i+\beta_2 \mathit{W}FLOODD_i + \lambda_t + \mu_i + trend_{jt} + \varepsilon_{it} \qquad (2)$$

where Y_{it} is either logged sales (SALE), logged employment (EMP), logged capital (CAPITAL), or labour productivity (SALE_EMP) of firm *i* at year *t*, and the other controls are defined as above, the only exception being the inclusion of firm-level fixed effects *μ*. This fixed effect serves to control for all time invariant factors, firm specific and otherwise (sector and location, for example), that may affect firm performance. For instance, if firms might prefer to locate in areas that are less (or more) susceptible to flooding, such as being near the water front, and those that can avoid doing so are also likely larger, then this potential confounding factor would be taking account of by the firm fixed effect. As before we cluster standard errors at the Chomé level.

One should note that (2) is akin to a spatial difference-in-difference (DID) estimator with continuous, i.e., not dichotomous, treatment (see Baum-Snow and Ferreira, 2015; Delgado and Florax, 2015), and a similar specification was used by Lima and Barbosa (2019) to estimate the impact of flash floods on regional GDP per capita in Brazil, except that in their context the treatment was dichotomous and the level analysis was not at the firm level. In our context the treated firms would be those that suffered flood damage, where treatment is continuous, and control firms would be those firms that did not suffer damage.

The firm level fixed effect μ absorbs any time invariant differences in the treatment and control groups, while the year dummies pick up any common factors in time. Thus the coefficients on FLOODD and WFLOODD are equivalent to the interaction term between the time of treatment and the level of treatment, i.e., the spatial DID effect. As before, the direct treatment effect is measured by β_1, the indirect treatment effect by β_2m and the average treatment effect by β_1,+ $\beta_2 WFLOOD^{MEAN}$, and excluding WFLOOD could produce biased estimates of the direct average treatment effect if there is correlation the response or treatment of storm sturge across space.

Causal identification of the direct indirect treatment effects of flooding in (2) rests on the assumption that there are no time varying factors that affected firm performance but were correlated with the inundation in a Chomé, or its neighboring Chomés. One should note in this regard that any location or production decisions taken with regard to expectations of the spatial distribution of storm surge would be absorbed by the firm fixed effects. In other words, after controlling for firm fixed effects, the variations in FLOOD and WFLOOD can be considered as draws from the inundation distribution within a Chomé. Our assumption here are that these draws are as good as random. This could be violated, for instance, if there was investment in infrastructure at the Chomé level prior to the flooding that caused changes firms' performance at the time of flooding but also reduced or increased the degree of flooding.[9] This unlikely to be the case for infrastructure directly related to flooding prevention, such as dykes, as there is little reason to believe why this would cause firm performance to change over time. In contrast, this could feasibly be the case for Chomé level differences in investment in infrastructure that reduces transport costs, such as railways, tramways, or roads, if these would also make Chomés more exposed to flooding. However, as long as the decisions of where to build such infrastructure is mostly taken at the Ward level and there are not too much differences in how these might affect exposure and/or firm performance within Wards, then the Ward specific time trends should take account of this.

5.Results

5.1 Firm Survival

5.1.1 Total Sample

The results from our Cox-Proportional Hazard model are given in Table 3 for the total sample, as well as sub-samples by sectors. As can be seen in the first column, for the total sample neither flooding in its own region nor in nearby regions affected firm exit. In terms of the other controls, the negative sign on SALE indicates that larger firms were less likely to shut down than smaller firms, One also discovers that a larger capital stock increased a firm's probability of shutting down.

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5.1.2 Sectoral Samples

As for the total sample, survival for firms operating in the construction sector was not significantly affected by either direct or indirect flood damages. However, somewhat surprisingly we find that for manufacturing firms more days under flooding in their own location decreased their likelihood of exit, while those in nearby regions increased the likelihood of ceasing production. Converting the estimated coefficients from the manufacturing regression to hazard ratios suggests that an extra day being flooded decreased a manufacturing firm's likelihood of exiting by close to 7%, as direct effect, while the average days flooded in affected neighboring regions increased it by 53% as an indirect effect.

In contrast to manufacturing, firms in both the wholesale and retail sectors had a higher probability of exiting the more flooding they were subjected to, where the corresponding increases per extra flood day were 22 and 19%. Additionally, for firms operating in the wholesale sector flooding in nearby regions tended to reduce the likelihood of closing down. Nevertheless, these spillover effects are relatively small, standing at 0.06% for the average number of flooding days.

5.2 Firm Performance

5.2.1 Total Sample

We depict the estimated impact of the damage variables on our measures of firm performance for the total sample in Table 4. As can be seen, there is no effect for sales, employment and labour productivity, neither directly nor indirectly, arising from being located in a Chomé that was flooded.

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In order to check the robustness of the lack of effect in the total sample we explored a number of aspects. Firstly, we examined whether the functional assumption of linearity of the effect of the number of flooding days may drive our lack of results. To this end we employed the semi-parametric estimator of Baltagi and Li (2002), which allows for a variable of interest to have a non-linear effect by modelling it using an Epanechnikov-kernel-weighted local polynomial fit. We show the results of this for all our firm performance variables and the two flood damage variables in the Appendix (Figure A1), and these indicate that non-linearity does not drive our results. Next we assume that any spillover can arise only through neighboring regions by creating a *W*FLOODD variable that was the simply average of FLOODD of all immediately adjacent regions. However, this does not produce any significant spillover effects, as reported in the Appendix (Table A1). Furthermore, since we do not have a measure of the height of flooding, we roughly proxy this by the mean elevation of the Chomé that a firm is located in, and investigated whether differences in elevation will alter our conclusions. This is done by interacting it with the flooding day measure and creating an analogous nearby region interaction term. However, these interaction terms are not significant (see Table A2). Finally, we explore using a lead indicator of the number of flood days, where we estimated whether the spatial spread flooding would be able to predict the pre-event measures of firm performance. More specifically, we assumed that the flood took place a year prior to its actual occurrence and regressed this on the firm measures in that prior year. The results, shown in the Appendix (Table A3) do not indicate that the number of flooding days was correlated with pre-event firm measures, and hence that the extent of flooding is not able to predict firm performance prior to the event.

Thus far we have only allowed for a one time permanent effect of flooding on the various aspects of firm performance. Feasibly, any effects may be different in the medium-term compared to the short-term, as firms may have time to adjust and/or postpone any changes temporarily, conditional on not shutting down. To investigate this further we extend the specification in (2) by allowing the estimated coefficients on the damage variables to change with the time passed after the typhoon. More specifically, we interacted each of the damage variables with dummy variables for each of the 4 years after the event. We depict the estimated coefficients for the total sample in Figure 3. Accordingly, the insignificant effects on sales, employment, and labour productivity hold over time, both in terms of direct and indirect damages. However, in terms of capital one finds that there is a significant increase in its value starting at three year after the storm, suggesting that overall surviving firms on average took the opportunity to upgrade their capital in response to the flooding damages in the medium term.

PLACE FIGURE 3 HERE

5.2.2 Sectoral Samples

As with firm survival, there may be considerable heterogeneity across sectors in how damages due to the Ise Bay Typhoon manifested itself in survivor post-performance. The results by sub-sample are shown for the construction, the manufacturing, the wholesale, and the retail sectors in Tables 5 through 8, respectively. For the construction sector, as shown in Table 5, one finds that flooding days reduced firm's sales significantly. The estimated coefficients suggest that for those firms that were in regions that were exposed to flood days, the average decrease in sales (using the mean non-zero flood days of our sample) was 7%. In contrast there was no discernible effect on employment or labour productivity in construction, either directly or indirectly, due to the typhoon.

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For manufacturing firms, as depicted in Table 6, there was no direct or indirect effect on either sales or employment. In contrast, after its locality being flooded, manufacturing firms increased capital, while flooding in nearby regions induced a reduction in capital. As shown in the last column of the table, labour productivity in firms in damaged areas increased as a result local flooding. In terms of quantitative effects, one finds that the average flooding caused a 4% increase in capital assets, while the average flooding in neighboring regions caused a 3% fall. The impact on labour productivity is relatively small, where even the maximum observed flooding days (23.5) would have caused only a 0.2% rise.

PLACE TABLE 6 HERE

In the wholesale sector, our results in Table 7 show that flooding caused a fall in both sales and capital, but no impact on employment and labour productivity. The coefficients suggest that the estimated mean effects of mean flooded days are 9% and 5% respectively for sales and capital. At the same time, there appear to have also been positive spillovers from damages in neighboring regions in terms of sales and employment, possibly indicating a surge in demand from other damaged regions. At face value, the average increases correspond to 9 and 4%, respectively. Finally, surviving firms in the retail sector appear to have benefited from being flooded, as indicated by significantly positive coefficient on sales in the first column of Table 8. As a matter of fact, the estimated coefficient suggests that each additional day flooded increased the sales of a retail firm that survived by 4%.

PLACE TABLES 7 AND 8 HERE

5.2.3 Sectoral Heterogeneity in Temporal Effects

Allowing for sector heterogeneity in temporal effects unearths further insight into the post-damage performance of firms. More specifically, as shown in Figure 4, one finds that the reduction in sales by direct damage (FLOODD) in construction firms is short-term, only lasting a year. In contrast, the increase in sales arising from spillovers from neighboring flooded regions (*W*FLOODD) continues over the entire spectrum of our post-event time horizon, suggesting that demand for reconstruction lasted at least up to the medium-term. The temporal decomposition also exposes the impact that flooding had on employment, where employment increased both as a result of direct and indirect damages, but for the latter only 3 years after the event Finally, the direct impact resulting in a rise in the capital stock is only apparent after two years, but then continues to rise. These changes by damage result in a fall in labour productivity for the last two years. Overall thus, local damages only have positive effects in the medium term, whereas spillover effects run throughout the post-flooding period.

PLACE FIGURES 4 AND 5 HERE

Figure 6 reports results on the wholesale sector. One can see that the countervailing effects of flood damages arising from local and nearby regional damages in the wholesale sector lasted up to three years after Typhoon Ise Bay. Through the temporal decomposition, these effects were also apparent in employment, although with a somewhat delayed timing. The average capital stock decreases observed are relatively consistent over time, except for at two years. One can now witness that there are short-term effects of flooding days on labour productivity, with falls due to direct and rise due to indirectly nearby damages.

PLACE FIGURE 6 HERE

Finally, for the retail sector Figure 7 demonstrates that the positive direct impact of flooded days on sales is persistent over our 4 year time frame. Additionally, we find a short-term negative effect on capital. In terms of the indirect effects, firms in the retail sector do not seem to be impacted.

PLACE FIGURE 7 HERE

6. Discussion

In this section we summarize our results and try to interpret them in light of potential explanations and what is known about the local context during the time of the typhoon strike.

6.1: Firm Exit

Our findings showed that overall there was no net impact of local storm surge after the Ise Bay Typhoon on firm exit in Nagoya City, in contrast to evidence found elsewhere in modern times after storm surge (see Craioveanu and Terrell, 2016, and Basker and Mirand, 2018). However, disaggregating the sample by sector showed that this net average zero effect was due to considerable sectoral heterogeneity. More specifically, as would be expected, local storm surge caused a greater likelihood of shutting down among both wholesale and retail firms. This findings may not be surprising given that Nagoya city had many small traditional wholesalers and retailers, which probably did not have enough facilities to prevent disasters (Yamaguchi, 2015). Thus much of the storage of wholesales and retails was lost by flooding (Hama, 2008), likely causing many of these to close down. One should note that this increased firm exit occurred despite the fact that many damaged retailers and department stores kept on their business even when their shops were damaged (*Chubu Nihon Newspaper*, 28 September and 5 October 1959). In contrast, more flood damage in neighbouring regions is likely to have boosted the local demand for such goods, plausibly explaining the local positive spillovers on wholesale firm survival.

Firm survival in the construction sector does not seem to have been affected by local storm surge. There may have been two opposing forces at work behind this finding. On the one hand, local storm surge is likely to have caused some damage to materials and buildings of construction firms, increasing their likelihood of shutting down. On the other hand, the demand for materials and work for recovery construction was enormously increased (Hama, 2008), possibly acting to buffer losses due to local damage.

Perhaps more surprisingly, the probability of manufacturing firms located in storm surge damaged areas increased after the storm, while damage in adjacent areas increased firm shutdown. As for the direct effect, there are two possible explanations for this arguably somewhat counter-intuitive result. Firstly, as mentioned above, some manufacturing firms in the bay area artificially raised their buildings to above the ground level before the typhoon, although this did not prevent some machines from being flooded by the high tide. This may raise survival rates for these firms (Science and Technology Agency, 1960; Central Disaster Management Council, 2008). Secondly, manufacturing firms were the main target for special bank loan programs, moratorium for bills, and bank's payment assistance for firm transactions (Central Disaster Management Council, 2008, p. 148)[10]. The financial aid was intensively allocated to seriously damaged manufacturing firms. For instance, the Daido Steel Company, which was one of the largest steel iron firms in Nagoya City was seriously damaged where all factories and dormitories were flooded and many employees and their families are dead (212 deaths) as a result of the storm surge. However, aid played a role in its recovery (Daido Steel Co., 2017). The positive impact on survival of being flooded suggests that these factors may have not only mitigated the impact of their own flood damage, but substantially decreased the probability of exit relative to those manufacturing firms that were not affected and did not receive such funds.

As for the negative spatial spillovers for manufacturing, there are also two possible reasons for this finding given the local context. First, Nagoya was a cluster of heavy manufacturing industries such as machineries. Since manufacturing firms in Nagoya transacted a number of intermediate inputs with many firms and affiliate companies nearby, serious flood damage of their intermediate-input firms impeded production chains after the typhoon (Aki, 1960).[11] Second, transportation systems were shut down for a long time by the large scale flood. This hampered firm's recovery due to the shortage of raw materials and intermediate inputs and no transportation routes for products (Central Disaster Management Council, 2008, p. 24). These indirect effects are likely to have increased the probability of exit of a manufacturing firm, congruent with our findings.

6.2 Firm Performance

As for firm exit, pooling firms across sectors also did not indicate a significant impact on firm performance of the survivors, and again, this masked sectoral heterogeneity. For firms operating in the construction sector we found that there was a consequent reduction in sales. One possible explanation is that local flooding, causing damages to materials, may have reduced a firm's own ability to profit from increased local demand for reconstruction, although, as noted above this fall in sales appears not to have been large enough to cause firms to shut down. In line with this as an explanation, we find that flooding in neighbouring regions increased sales, likely due to increased demand for construction activities in nearby regions that were damaged. In terms of capital we find that the number of locally flooded days affected capital positively in construction firms, where a firm located in a flooded region increased its capital ex post the event by 6%. Thus construction firms appear to have upgraded their likely damaged capital after the storm. At the same time, we also found that employment increased, although not immediately, in line with the findings for the US by Strobl and Walsh (2009). Putting our findings for the construction sector into the historical context, one should note that after the typhoon the government invested in several large-scale projects of high tide and flood control with advanced technology across Nagoya city (Central Disaster Management Council, 2008, pp. 149-150). Thus possibly, since the construction required high technology and advanced equipment, if contracts were preferably given to damaged construction firms, then these would have needed to upgrade their capital. Nevertheless, the fall in labour productivity indicates that perhaps machines were substituted for labour as a consequence.

For the manufacturing sector, storm surge damage caused a rise in capital if it occurred in its own area, and a fall in response to damage in adjacent areas. The upgrading of capital is supported by what is known about the context after the event, where it has been reported that many manufacturing firms in Nagoya city increased capital investment after the typhoon. For example, the inundation by sea water caused the motors of many machines to malfunction, so that new machines had to be installed. Furthermore, some factories newly constructed high-tide walls and water-proof facilities (e.g. Mimura, 1992)[12], and many invested in large scale drainage and soil improvements (Architectural Institute of Japan, 1961; Central Disaster Management Council, 2008, pp. 142-146).[13] This upgrading of material capital after natural disasters, such as the renewal of machines and facilities, is known as creative destruction in the literature (Pereira, 2009; Imaizumi et al., 2016; Cole et al., 2018; Okazaki et al., 2019).[14] Accordingly, natural disasters may offer opportunities to upgrade technologies and production techniques. The fact that labour productivity in the manufacturing sector fell at the same time may mean that the affected firms in manufacturing, like construction firms, may have used this opportunity to replace labor with newer machines. Negative spillovers on capital from flooding in nearby regions may simply be the flipside of this story, i.e., neighboring firms that acquired newer technology after being flooded provided greater competition, and thus less incentive for local firms to upgrade machines.

For the wholesale sector our analysis indicates that for surviving firms sales, employment, and capital stock fell as a consequence of local flooding, and all generally for more than a year, although their timing was not perfectly synchronous. At the same time, there were positive spatial spillovers on sales and employment, but not on capital, from damages in other regions. Again, this may have been due to local production falling as a result of local damage, but increasing in response to less competition from damaged firms nearby.

Finally, for retailers, the most striking effect is a persistent positive impact of local storm surge on sales. Again, the historical context can serve to provide some explanation for this. First, as mentioned earlier, surviving damaged retailers were generally able to continue their business and their recovery was relatively quick (*Chubu Nihon Newspaper*, 28 September and 5 October 1959; *Chubu Nihon Newspaper*, 27 December 1959). The second reason may have been an existent law on the association of shopping streets (the Shopping District Promotion Cooperatives Act), which was established in 1962 to provide financial support to retailers after a disaster (All Japan Association of Shopping Districts, 1962). As a matter of fact, the supertyphoon severely damaged several of these shopping streets and it would have been difficult to recover for some firms due to a lack of financial access. The establishment of the law helped small affected retailers and possibly contributed to their persistent rise of sales even well after the flooding (Nagoya city, 2012; Hama, 2008).

7. Conclusion

In this paper, we investigated the short- and medium-term impact of Supertyphoon Vera (1959) on firms in various sectors that were flooded during the storm. Our econometric results using firm-level data shortly before and several years after the event, as well as a localized damage proxy based on a historical flood inundation map, show that the flooding caused by the supertyphoon did not always cause some firms in all sectors to go out of business and the flood damage of neighbouring area helped some firms' survival due to increased local demand for recovery.

Conditional on having survived, decomposing our sample into manufacturing, wholesale, retail and construction, also revealed considerable sectoral heterogeneity in firm performance. In manufacturing, capital growth simultaneously increased as a consequence, suggesting that the supertyphoon might have been used as an opportunity to upgrade capital. In contrast, wholesale sector firms were characterized by a reduction in sales and capital if they experienced local flood damage, but sales and employment increased when nearby regions were affected. While there were no regional spillover effects for firms operating the retail sector, they did experience a surge in sales even up to the medium-term after the event. More generally, we showed that there were some differences in our results in the short- compared to the medium-term.

One aspect that stands out in the sectoral analysis is that there is evidence of creative destruction for some industries attributable to the flooding after the storm, but that this depends on the sector. This finding of sectoral heterogeneity may very well explain why the evidence regarding creative destruction in the existing literature is rather mixed (Noy and du Pont, 2018). Alternatively, the existence of creative destruction may simply be context specific. At any rate, the considerable heterogeneity we find here suggests that there is unlikely to be any one-size-fits-all policy to consider in ex-post disaster management. Rather, a thorough of understanding of which and how sectors are affected could allow policymakers to be much more efficient in resource use to limit the impact of natural disasters, such as storm surge. Important in this context would be to also take into account potential spatial spillovers effects of storm surge damages. In particular, realizing that horizontal linkages and markets may be spatially very wide and thus even if a firm itself is not directly damaged, damages in other areas can have nevertheless an impact.

One should note that one weakness of our analysis is that we are only able to capture the net effect as measured by direct damage, proxied by the number of days flooded, and indirectly as spatial spillover effects from nearby regions. However, one reason for interruptions to normal business activity after the typhoon was that many workers could not return to work because their own residences were damaged or perhaps because they themselves were injured or dead. Unfortunately, our data does not allow us to link a firm's workers to their residence or their health. If this effect is large, this could imply that there is considerable measurement error in our measure of damages as a proxy for such non-direct effects, leading to a downward bias in our estimates. Also, ideally we would have liked to have as an additional control group data for comparable firms operating in similar sectors in another, unaffected, city. Unfortunately such data was not available. Thus our results can only be interpreted in terms of the causal effect relative to non-affected firms in the same city, where this is conditional on how we specifically define treatment and our identifying assumptions. One should also point out that the context in which we examined the impact of damages due to a very damaging natural disaster event is arguably very specific, both in terms of the local economic structure, history of previous events, and disaster policy (non-)existence. Thus our findings may not necessarily hold for more modern settings, or even other historical contexts within the same period.

Finally, one should note that our results are somewhat different from those of Lima and Barbosa (2019), who investigated the impact of the flash flood of 2008 on municipality level GDP per capita in Brazil. While they find a direct impact of a 7.6% decrease of the floods, GDP rebounded to pre-disaster levels just three years after the event. Moreover, the indirect impact by spatial spillovers in Brazil was shown to be negative. By contrast, in our study the impacts are more persistent and we identify the heterogeneity across sectors. But this must be considered in terms of the differences of the studies. Firstly, we are examining firms rather than regions. Moreover, our regional units that determine the spatial differences in flooding are much smaller than the size of Brazilian municipalities. Second, the Ise Bay typhoon of 1959 was the last event before the central government conducted disaster-risk reduction, such as co-ordinated disaster prevention and manages post-disaster recovery process. In this sense, the post-disaster growth was arguably generally not net of the influence of policies. As such our study can perhaps serve as a good example of the effects of storm surge if no significant disaster-risk reduction policies are in place.

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Table 1: Damage in Nagoya City

	Damage	Number
Human Damage (unit:person)	Dead	1,851
	Missing	58
	Seriously injured	1,619
	Injured	38,909
	Total	42,379
Building Damage (num buildings)	Totally collapsed	6,166
	Washed away	1,557
	Partially collapsed	43,249
	Inundated	67,352
	Total	118,324

Source: Nagoya city (1989)

Table 2: Summary Statistics

	Total				Before				After			
	Mean	Std.Dev.	Min.	Max.	Mean	Std.Dev.	Min.	Max.	Mean	Std.Dev.	Min.	Max.
SALE (‘000s)	81.9	954.6	0.2	800005.0	57.6	499.0	0.2	2000.0	89.4	1056.0	0.3	8005.0
EMP	133	589	2	18005	97	383	2	10040	145	640	2	18005
CAPITAL (‘000s)	6.41	124.67	0.05	8100.0	2.80	41.44	0.05	1800	7.54	140.7	0.01	8100
SALE_EMP (‘000s)	2.27	106.61	8.69e-04	100.63	2.80	11.6	8.69e-04	100.0	2.58	121.9	0.003	100.63
FLOODD	1.14	3.34	0	24.75	0	0	0	0	1.56	3.77	0	24.75
WFLOODD	0.067	0.114	0	0.663	0	0	0	0	0.089	0.12	0.0003	0.663
AGE_{t-1}	10	8	0	68	8	7	0	63	9	8	1	68

Table 3: Firm Exit

Sample:	(1) All	(2) Construction	(3) Manufacturin g	(4) Wholesale	(5) Retail
FLOODD	0.00910	-0.0752	-0.0709**	0.203***	0.176**
	(0.0632)	(0.0578)	(0.0360)	(0.0678)	(0.0870)
WFLOODD	-0.0359	1.771	1.791**	-5.992**	-2.638
	(1.563)	(2.605)	(0.850)	(2.632)	(3.830)
AGE	0.000630	0.0362	-0.000844	-0.00252	0.00673
	(0.00574)	(0.0535)	(0.00825)	(0.00889)	(0.0201)
SALE	-0.387***	-1.364***	-0.324***	-0.256***	-0.654***
	(0.0518)	(0.419)	(0.0837)	(0.0925)	(0.130)
EMP	-0.0568	-0.137	0.00592	-0.199	0.0576
	(0.0620)	(0.290)	(0.102)	(0.125)	(0.155)
CAPITAL	0.109**	0.849**	0.0637	0.0763	0.182
	(0.0433)	(0.335)	(0.0725)	(0.0879)	(0.126)
Observations	7,272	283	2,564	2,713	1,331
Firms:	2093	83	742	764	377
Pseudo R^2	0.0148	0.189	0.0163	0.0305	0.0438

(a) Standard errors clustered at the Chomé level in parentheses, (b) *** p<0.01, ** p<0.05, * p<0.1; (c) Sector dummies and Ward dummies included, but their estimates not reported; (d) Econometric model is a Cox-Proportional Hazard Model, as specified in Equation (1).

Table 4: Firm Performance – Total Sample

Dep. Var.:	(1) SALE	(2) EMP	(3) CAPITAL	(4) SALE_EMP
FLOODD	-0.00334	-0.000930	0.00613	-0.00333
	(0.00518)	(0.00314)	(0.00472)	(0.00251)
WFLOODD	0.134	-0.00148	-0.135	0.0795
	(0.165)	(0.0999)	(0.134)	(0.0576)
Observations	8,826	8,826	8,826	8,826
Number of firms	2,089	2,089	2,089	2,089
R-squared	0.325	0.225	0.359	0.002

(a) Standard errors clustered at the Chomé level in parentheses, (b) *** p<0.01, ** p<0.05, * p<0.1; (c) Year dummies and Ward specific time trends are included but their estimates not reported; (d) Econometric model is a firm level fixed effects panel linear model as specified in Equation (2).

Table 5: Firm Performance – Construction

Dep. Var.:	(1) SALE	(2) EMP	(3) CAPITAL	(4) SALE_EMP
FLOODD	-0.0305*	0.00341	0.0272*	-0.000117
	(0.0163)	(0.0160)	(0.0141)	(9.71e-05)
WFLOODD	1.082**	0.260	-0.350	0.00352
	(0.452)	(0.436)	(0.392)	(0.00279)
Observations	344	344	344	344
Number of id	83	83	83	83
R-squared	0.694	0.226	0.578	0.294

(a) Standard errors clustered at the Chomé level in parentheses, (b) *** p<0.01, ** p<0.05, * p<0.1; (c) Year dummies and Ward specific time trends are included but their estimates not reported; (d) Econometric model is a firm level fixed effects panel linear model as specified in Equation (2).

Table 6: Firm Performance – Manufacturing

Dep. Var.:	(1) SALE	(2) EMP	(3) CAPITAL	(4) SALE_EMP
FLOODD	0.00117	-0.00250	0.0146**	7.34e-05**
	(0.00649)	(0.00420)	(0.00627)	(3.24e-05)
WFLOODD	-0.0520	-0.0900	-0.387**	-0.000673
	(0.186)	(0.127)	(0.186)	(0.00117)
Observations	3,062	3,062	3,062	3,062
Number of id	742	742	742	742
R-squared	0.331	0.199	0.391	0.019

(a) Standard errors clustered at the Chomé level in parentheses, (b) *** p<0.01, ** p<0.05, * p<0.1; (c) Year dummies and Ward specific time trends are included but their estimates not reported; (d) Econometric model is a firm level fixed effects panel linear model as specified in Equation (2).

Table 7: Firm Performance – Wholesale

Dep. Var.:	(1) SALE	(2) EMP	(3) CAPITAL	(4) SALE_EMP
FLOODD	-0.0394**	-0.0107	-0.0201**	-0.0194
	(0.0183)	(0.00836)	(0.00908)	(0.0119)
WFLOODD	1.044**	0.447**	0.350	0.404
	(0.455)	(0.225)	(0.257)	(0.256)
Observations	3,292	3,292	3,292	3,292
Number of id	764	764	764	764
R-squared	0.268	0.283	0.324	0.004

(a) Standard errors clustered at the Chomé level in parentheses, (b) *** p<0.01, ** p<0.05, * p<0.1; (c) Year dummies and Ward specific time trends are included but their estimates not reported; (d) Econometric model is a firm level fixed effects panel linear model as specified in Equation (2).

Table 8: Firm Performance – Retail

	(1)	(2)	(3)	(4)
Dep. Var.:	SALE	EMP	CAPITAL	SALE_EMP
FLOODD	0.0426***	0.00549	-0.0153	9.98e-05
	(0.0146)	(0.00665)	(0.00956)	(0.000152)
WFLOODD	-0.571	-0.202	-0.171	0.00297
	(0.747)	(0.298)	(0.265)	(0.0104)
Observations	1,606	1,606	1,606	1,606
Number of id	377	377	377	377
R-squared	0.385	0.257	0.377	0.054

(a) Standard errors clustered at the Chomé level in parentheses, (b) *** p<0.01, ** p<0.05, * p<0.1; (c) Year dummies and Ward specific time trends are included but their estimates not reported; (d) Econometric model is a firm level fixed effects panel linear model as specified in Equation (2).

Figure 1: Storm Surge Flooding – Number of Firms in Sample

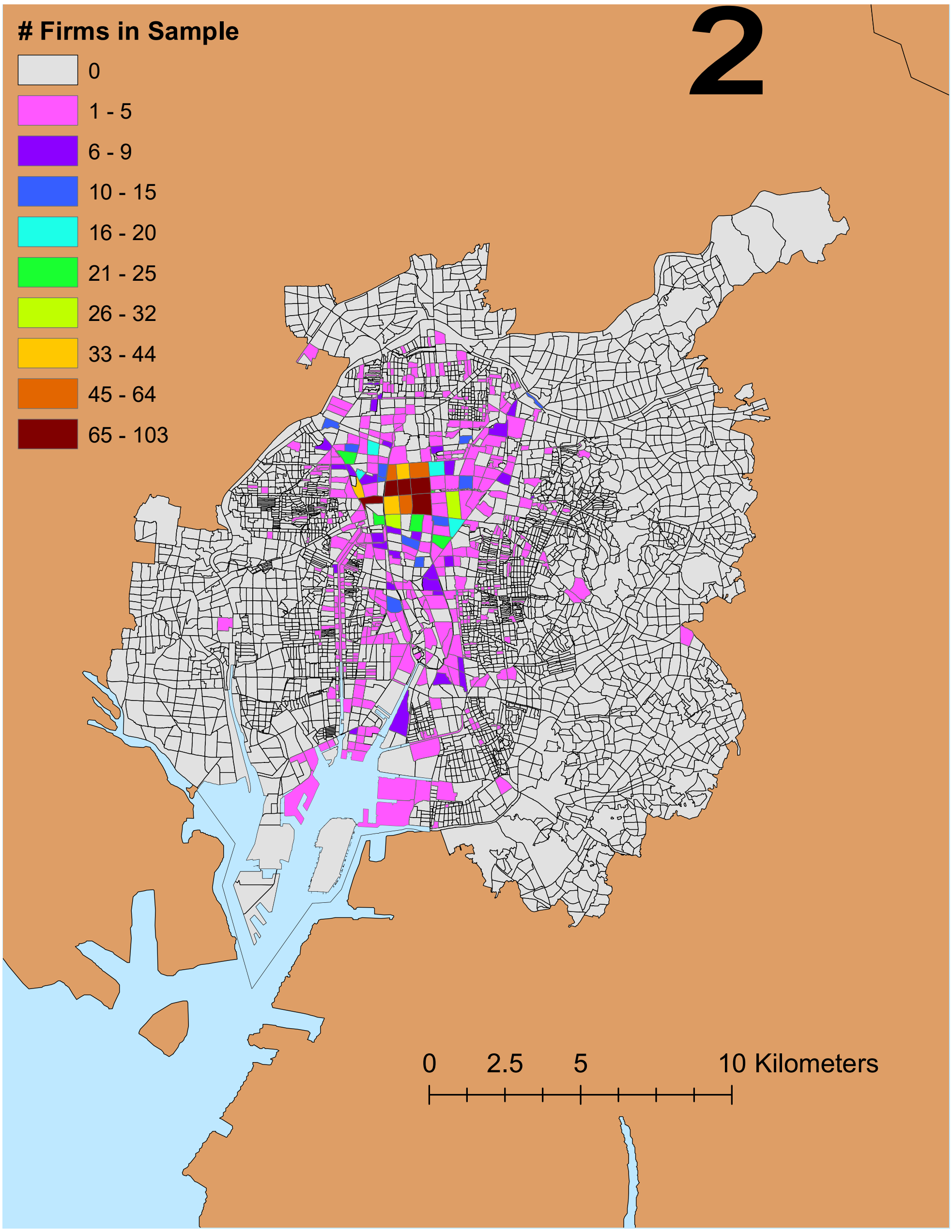


Figure 2: Storm Surge Flooding – Number of Days Flooded

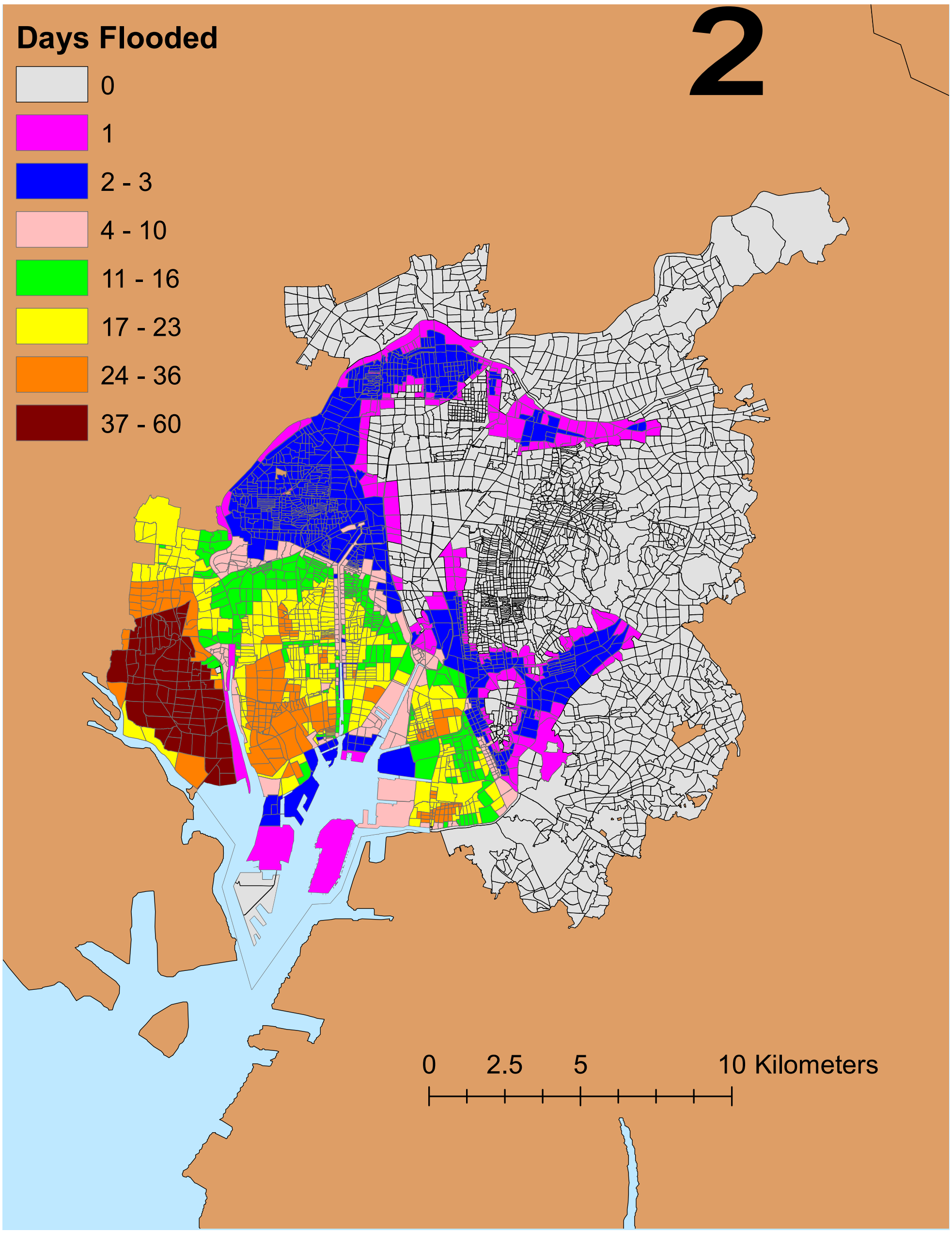
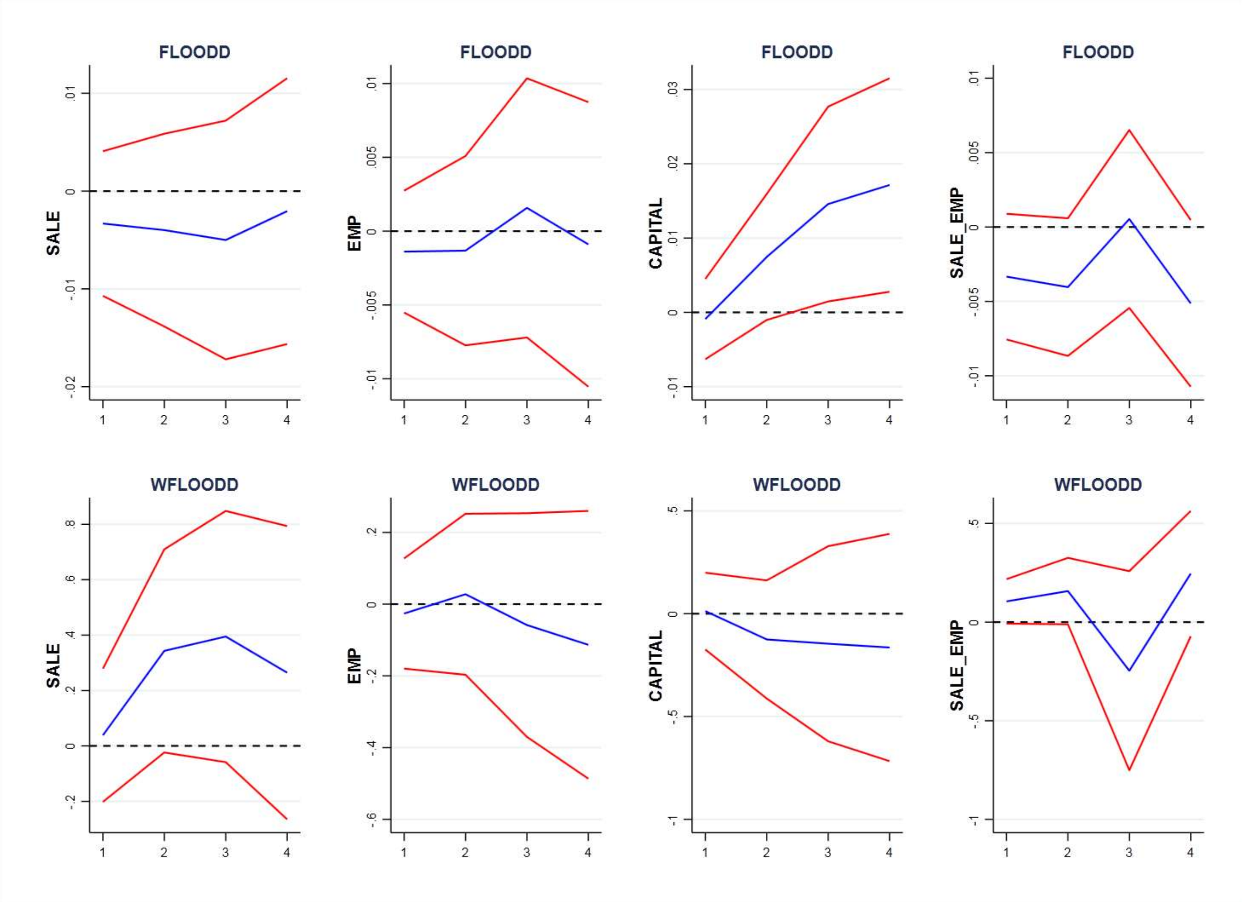
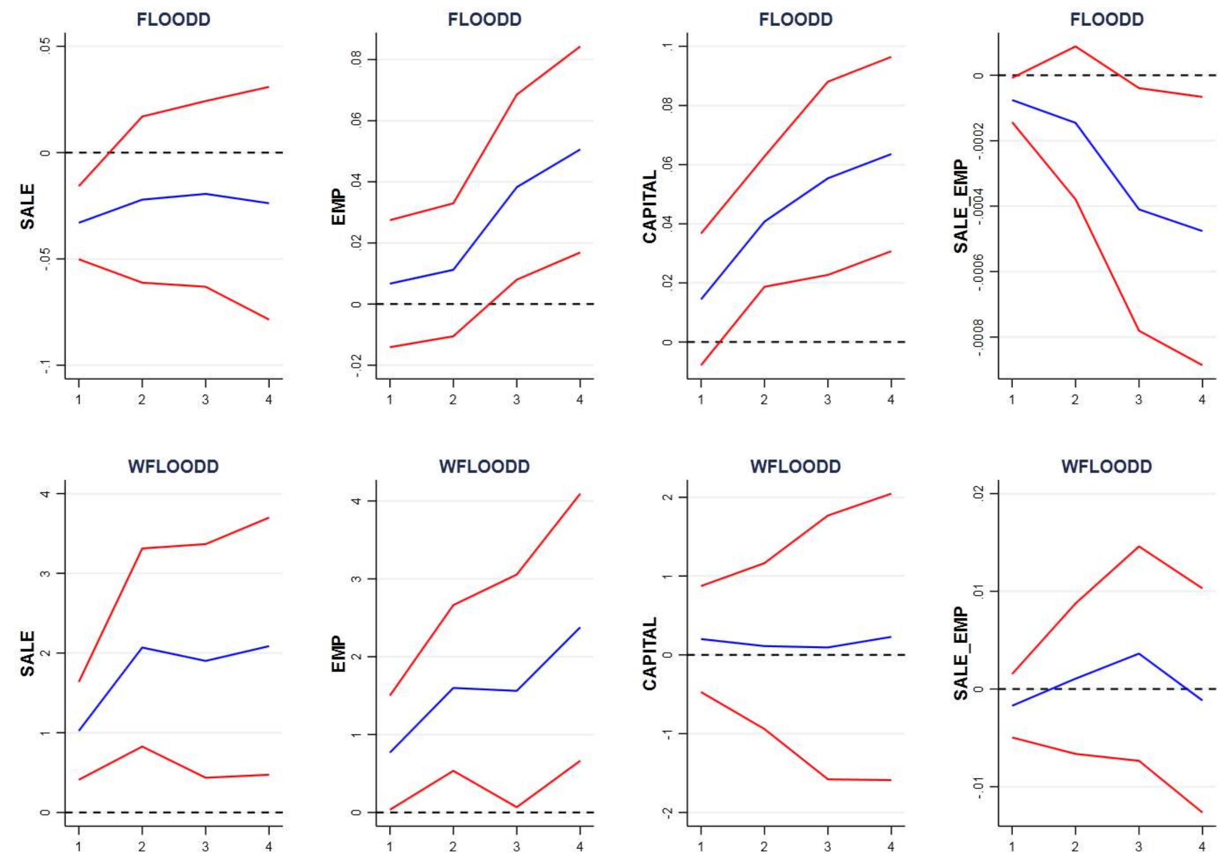


Figure 3: Temporal Effects– Total Sample



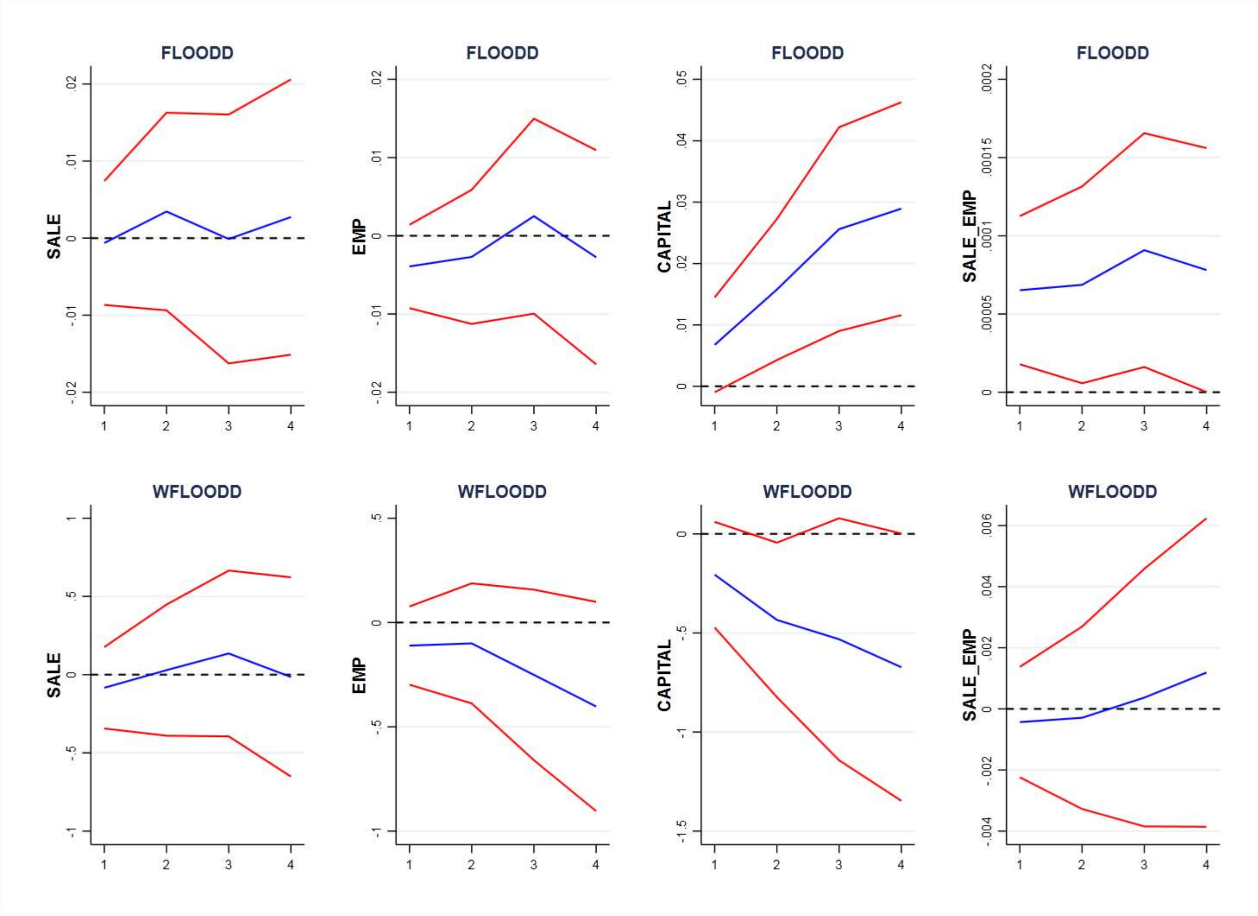
Notes: (a) Blue lines are estimated coefficients over time on FLOODD and WFLODD; (b) Red lines are 90% confidence bands.

Figure 4: Temporal Effects– Construction



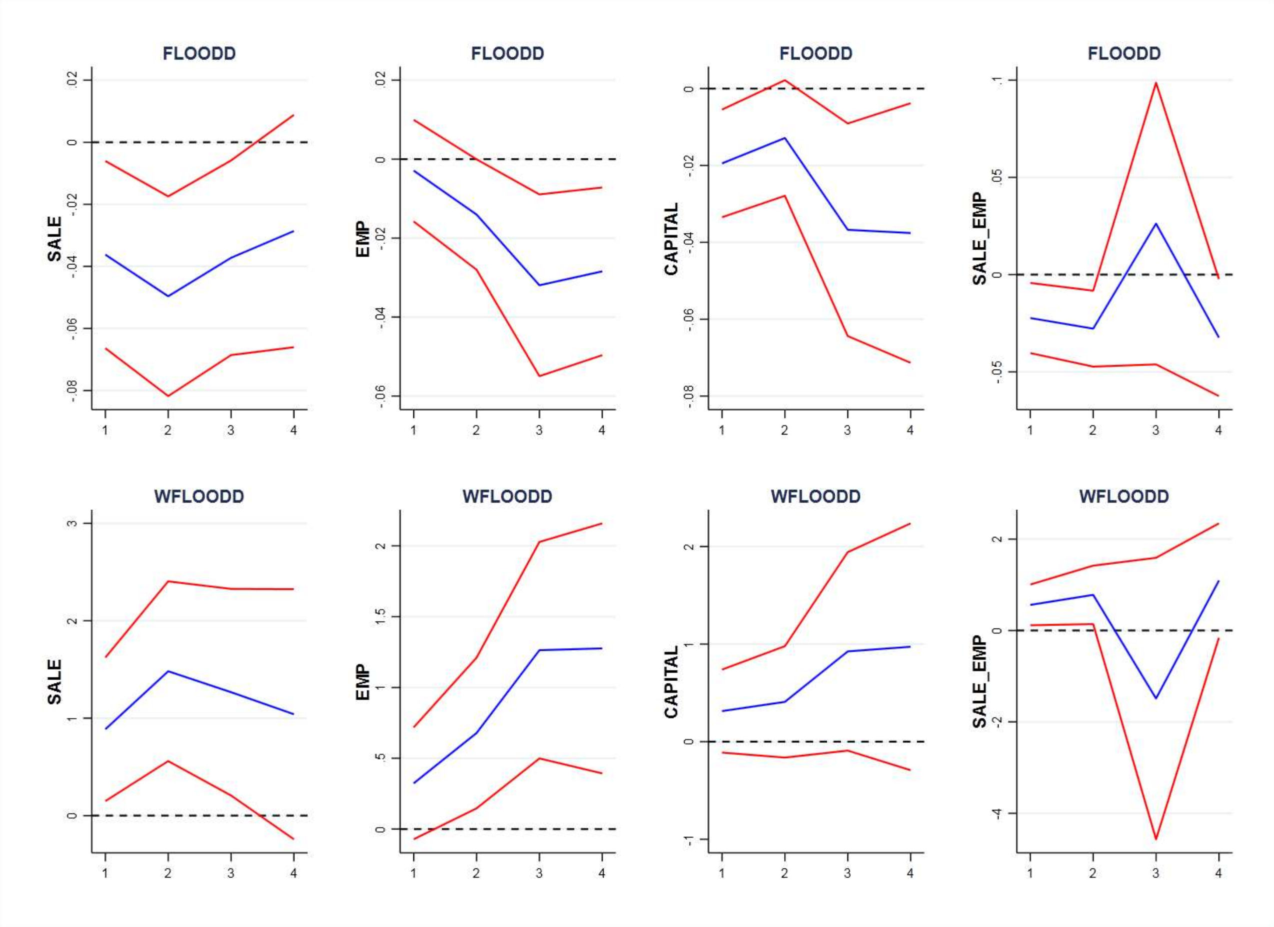
Notes: (a) Blue lines are estimated coefficients over time on FLOODD and WFLODD; (b) Red lines are 90% confidence bands.

Figure 5: Temporal Effects– Manufacturing



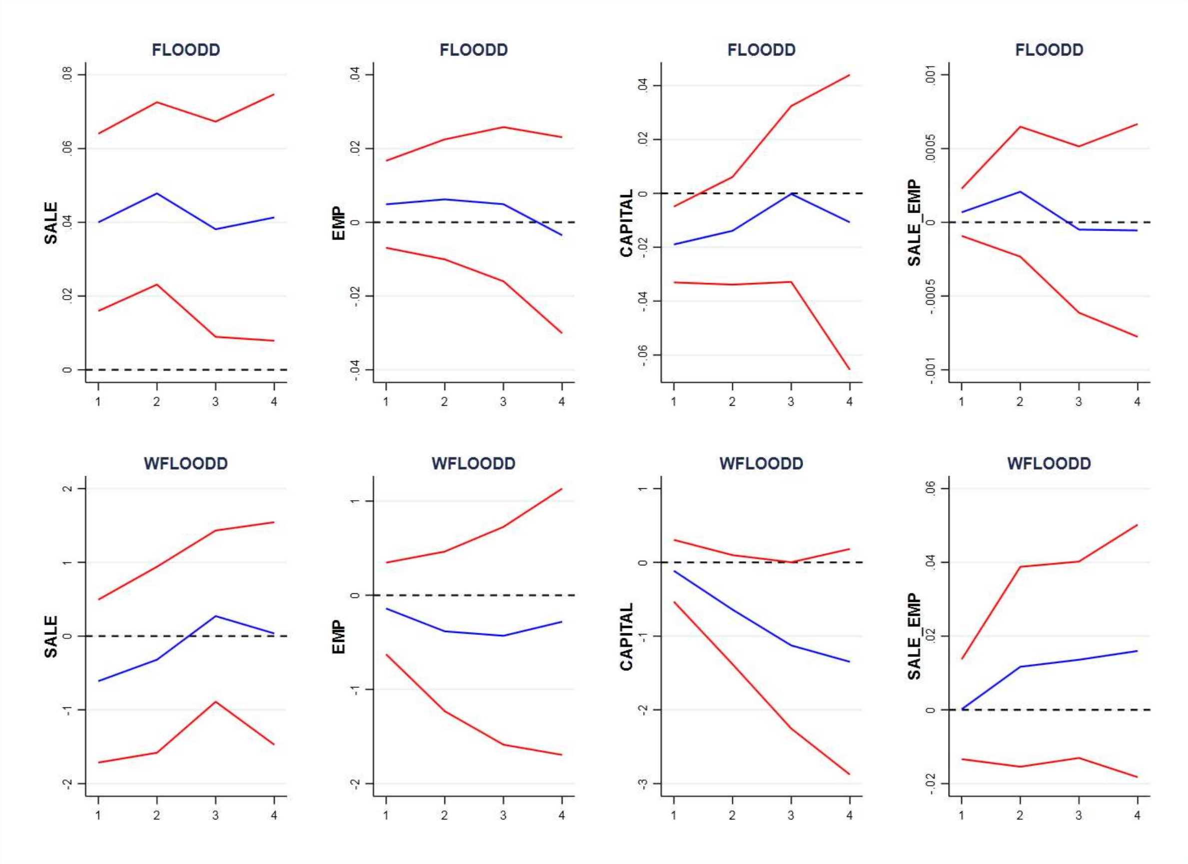
Notes: (a) Blue lines are estimated coefficients over time on FLOODD and WFLODD; (b) Red lines are 90% confidence bands.

Figure 6: Temporal Effects– Wholesale



Notes: (a) Blue lines are estimated coefficients over time on FLOODD and WFLODD; (b) Red lines are 90% confidence bands.

Figure 7: Temporal Effects– Retail



Notes: (a) Blue lines are estimated coefficients over time on FLOODD and WFLODD; (b) Red lines are 90% confidence bands.

APPENDIX

Table A1: Firm Performance – Total Sample; Adjacent Neighbor Spillovers

Dep. Var.:	(1) SALE	(2) EMP	(3) CAPITAL	(4) SALE_EMP
FLOODD	-0.000415	0.000529	0.00720	-0.00282
	(0.00537)	(0.00358)	(0.00438)	(0.00226)
WFLOODD	-0.000627	-0.00622	-0.0161	0.00476
	(0.0160)	(0.00793)	(0.0114)	(0.00387)
Observations	8,826	8,826	8,826	8,826
Number of firms	2,089	2,089	2,089	2,089
R-squared	0.325	0.225	0.359	0.002

(a) Standard errors clustered at the Chomé level in parentheses, (b) *** p<0.01, ** p<0.05, * p<0.1; (c) Year dummies and Ward specific time trends are included but their estimates not reported; (d) Econometric model is a firm level fixed effects panel linear model as specified in Equation (2); (e) WFLOOD defined as average among contiguous neighboring Chomes.

Table A2: Firm Performance – Elevation Differences

Dep. Var.:	(1) SALE	(2) EMP	(3) CAPITAL	(4) SALE_EMP
FLOODD	0.00177	0.00611	0.00335	0.000790
	(0.00747)	(0.00510)	(0.00765)	(0.000785)
WFLOODD	0.311	-0.281*	-0.0782	0.0684
	(0.297)	(0.164)	(0.265)	(0.0448)
FLOODD*EL	-0.00137	-0.000987	0.000482	-0.000839
	(0.00120)	(0.000877)	(0.000969)	(0.000501)
WFLOODD*EL	-0.702	0.771*	-0.125	-0.0556
	(0.755)	(0.462)	(0.654)	(0.0710)
Observations	8,826	8,826	8,826	8,826
Number of firms	2,089	2,089	2,089	2,089
R-squared	0.326	0.226	0.359	0.002

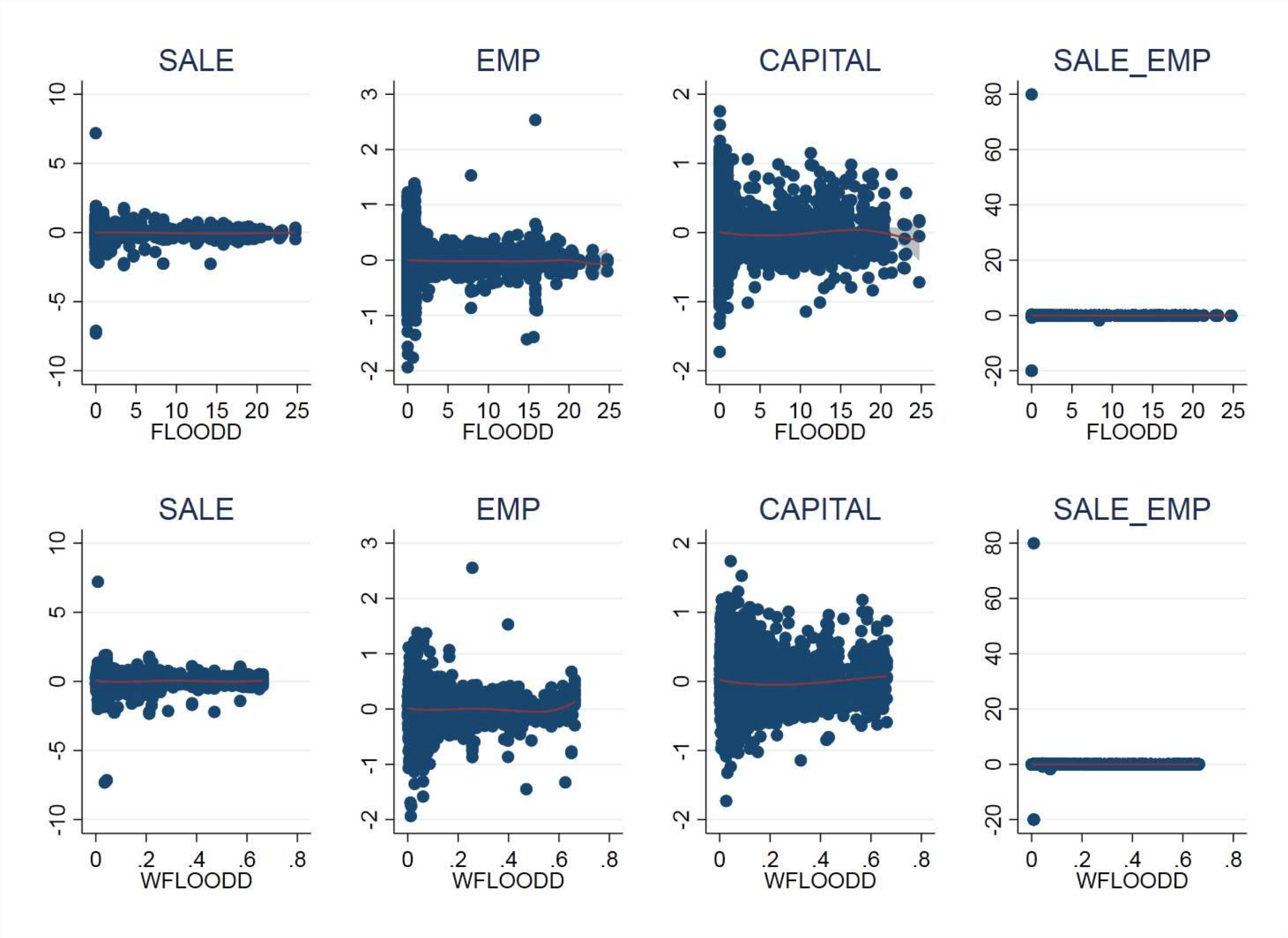
(a) Standard errors clustered at the Chomé level in parentheses, (b) *** p<0.01, ** p<0.05, * p<0.1; (c) Year dummies and Ward specific time trends are included but their estimates not reported; (d) Econometric model is a firm level fixed effects panel linear model as specified in Equation (2); (e) EL: average elevation.

Table A3: Firm Performance – Total Sample; Lead Effect

Dep. Var.:	(1) SALE	(2) EMP	(3) CAPITAL	(4) SALE_EMP
FLOODD	0.00334	0.000930	-0.00613	0.00333
	(0.00518)	(0.00314)	(0.00472)	(0.00251)
WFLOODD	-0.134	0.00148	0.135	-0.0795
	(0.165)	(0.0999)	(0.134)	(0.0576)
Observations	8,826	8,826	8,826	8,826
Number of firms	2,089	2,089	2,089	2,089
R-squared	0.325	0.225	0.359	0.002

(a) Standard errors clustered at the Chomé level in parentheses, (b) *** p<0.01, ** p<0.05, * p<0.1; (c) Year dummies and Ward specific time trends are included but their estimates not reported; (d) Econometric model is a firm level fixed effects panel linear model as specified in Equation (2); (e) FLOODD and WFLOODD defined as occurring one year earlier than in actuality.

Figure A1: Non-Linear Impact



Notes: (a) Scatter plot of flood variables and firm performance measures; (b) Red lines are Semi-parametric estimates of relationship between flood variables and firm performance measures.

[11] Typhoons are referred to as supertyphoons if they reach maximum sustained 1-minute surface winds of at least 241 km/hr, i.e., the strength equivalent of a hurricane in the North Atlantic Basin of at least a category 4 according to the widely used Saffir–Simpson Scale.

[2] The Japan Meteorological Agency (JMA) also named the storm "Ise-wan" after Ise Bay, the bay area of Nagoya City, in addition to its other names, i.e., Supertyphoon Vera and the Ise Bay Typhoon.

[3] Husby et al. (2014) investigate the impact of the 1953 flooding in the Netherlands on the long- and short-run population dynamics in the damaged regions, while it had a negative impact on the population in the regions in the short-run. The impact of floods on regional growth in Brazil is studied by Lima and Barbosa (2019), who find that regions directly affected by the 2008 flooding in Santa Catarina decreased GDP per capita by 7.6% but recovered all sectors except agriculture after three years. In addition, de Oliveira (2019) studies the damage caused by these floods in the Brazilian agricultural sector. Noy et al. (2019) studies the impact of the 2011 flood in Thailand on household behavior.

[4] However, the soaring land prices in the canal area before WWII made it difficult for many new firms to choose a location in southern Nagoya City; instead, they tended to choose northern areas.

[5] Another seriously damaged area was the town adjacent to Nagoya City, i.e., Ama County. However, we did not include the area in our sample because there were only a few firms with capital assets over 1 million yen located in Ama County and it was mainly an agricultural area.

[6] If spatial correlation or interaction of treatment response of flooding is present, then the direct treatment effect is measured by β_1, the indirect treatment effect by β_2m and the average treatment effect would be β_1,+ $\beta_2 WFLOOD^{MEAN}$.

[7] Since firm exit is a non-repeated event one cannot control for firm fixed effects within a Cox-Proportional Hazard modeling framework (Allison, 1996).

[8] Infrastructure projects after the typhoon were large-scale. For example, the recovery construction such as drainage and repair of embankments was done in over 220 places with 33 km by the collaboration of Ministry of Agriculture, Ministry of Construction, Aichi prefecture and Mie prefecture (Central Disaster Management Council, 2008, p. 148).

[9] If infrastructure was built as a consequence and as a function of the degree of flooding this would not violate the identifying assumption, but would simply imply that any estimated effect is net of ex-post policy response.

[10] Other than the financial aid, manufacturing factories were allowed to receive advance payment for their produced products and postpone payments for raw materials and intermediate inputs to use.

[11] According to Aki (1960), Toyota automobile company, which was located in the outskirts of Nagoya city, stopped operation for a moment because more than 150 parts and components firms located in Nagoya city were seriously damaged by flood and telecommunication was stopped inside Nagoya city.

[12] Mimura(1992) provided a case study on Toray Co., a major textile company in Nagoya city. He showed some damage by flooding and the adaption of new water-proof machines and facilities after the typhoon. See also Nagoya City (1989, 2012).

[13] According to Central Disaster Management Council (2008), there were several problems after the settlement of drainage. Disinfection and sterilization were one issue. More time-spending was to exclude a large number of lumbers, which were originally kept in lumberyard in the Bay of Nagoya and pushed into inland by high tide. See also Tani (1960)

[14] A number of theoretical papers have explored creative destruction after a natural disaster (Okuyama, 2003, 2019; Hallegatte and Dumas, 2009). They indicate that natural disaster would not lead to creative destruction. However, a few studies investigated this possibility empirically, although the results have been mixed. For instance, Pereira (2009) and Imaizumi et al. (2016) find improvements in the long-run economic performance after natural disasters (i.e., the 1755 Lisbon Earthquake and the 1923 Great Kanto Earthquake in Tokyo, respectively). Using firm-level machine data, Okazaki et al. (2019) show that the

growth of machine qualities in manufacturing firms after the 1923 Great Kanto Earthquake in Tokyo. Using plant-level data, Cole et al. (2018) find that plant birth increased in severely damaged areas after Kobe Earthquake in Japan. Turning to developing countries, Cuaresma et al., (2008) does not find clear creative destruction.