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伊勢湾台風における企業の存続と成長

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【要旨】

本研究では1959年の伊勢湾台風における名古屋市内の企業の存続と成長をミクロデータと丁目レベルの浸水日数を用いて計量分析した。

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

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Abstract

This paper investigates the damage impact of the 1959 Ise Bay Typhoon—the most destructive storm in Japanese history—on firm performance in Nagoya City. To this end, we combine firm-level data with a locally derived damage index measured in terms of the duration of storm surge-induced flooding. We find heterogeneous impacts of flood damage across firms and sectors. More specifically, older manufacturing firms tend to survive and, conditional on survival, longer time inundation moderated their employment and sales growth, but also promoted capital growth, suggesting investment in new machinery and facilities. In contrast, employment growth increased in the construction sector to satisfy the construction demand for rebuilding after the supertyphoon.

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

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

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1. Introduction

Supertyphoon[2] Vera, also known as the Ise Bay Typhoon, made landfall in Japan on the 26th of September 1959. The supertyphoon reached maximum wind levels of up to 258 km/hr resulting in storm surges of nearly 4 m. This supertyphoon is arguably the most infamous tropical cyclone in the history of Japan. It was the most destructive storm in modern Japanese history, 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 could 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,[3] 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),[4] studies on

[2] Typhoons are referred to as supertyphoons if they reach a 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 a strong category 4 or category 5 according to the widely used Saffir–Simpson Scale.

[3] 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.

[4] 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. The flooding 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

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.

In this paper, we build on the existing research by investigating the possibly heterogeneous impact of the Ise Bay Typhoon on manufacturing firms, retailers/wholesalers, and other firms (i.e., construction firms) of Nagoya City on their survival as well as the effect on sales, employment, productivity, and capital growth 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 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 direct 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 and firms using firm-level data as well as small district-level damage 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 for firms and geo-reference a detailed map of the 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 after the typhoon. This provides us with a unique data set that allows us to examine how flooding after the typhoon affected survival and post-survival performance in the short-term.

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

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.

and provide summary statistics. Section 4 contains our econometric analysis. 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 a central component of the country's big industrial bloc, but the city has been a commercial and manufacturing centre 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. However, the soaring land prices in the canal area made it difficult for many new firms to choose a location in southern Nagoya City; instead, they tended to choose northern areas (Numajiri, 1995, 2002).

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 related military firms, such as aircraft firms, became concentrated in Nagoya. However, Nagoya City was severely damaged by 38 US air raids during WWII, where around 25% of the city was completely burnt down. In the post-war period, Nagoya City immediately initiated a new urban planning policy (Numajiri, 2002). This new zoning, supported by a land adjustment policy, was similar to the pre-war one in terms of areas and categories (i.e., manufacturing and commercial areas). More specifically, the manufacturing area was again designed to be located along the south–north corridor from Nagoya

Port to the northern city centre via Nakagawa Canal, while the commercial area was reconstructed in the eastern area of Nagoya Central Railway Station. After WWII, many manufacturing firms in textiles, pottery, and sewing machine industries started operating in the manufacturing area, which contributed to boosting economic recovery in Nagoya City. In the 1950s, some unused lands from pre-war large military installations, manufacturing factories or public factories were replaced by new entrants. New industries such as motorcycle manufacturing emerged in the 1950s. Even after the destruction caused by the Ise Bay Typhoon, Nagoya City continues 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. The frequently flooded Shin-Horikawa River running through Nagoya City was excavated to reduce flooding since the Edo period and construction finally finished by 1910. Nevertheless, Nagoya City afterwards still experienced incidences of flooding due to several large typhoons. For example, a large typhoon hit the city on 15 August 1907 and 22 people died while 4,827 ha of agricultural fields were inundated. On 22 to 23 September 1912, a large typhoon with a high tide reaching 4.6 m resulted in 155 people dead and 9258 buildings 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. After the typhoon, Nagoya City undertook some measures for disaster prevention, such as physically fixing ships and timbers to the quay during typhoons. However, the demand for timbers increased and the timber export industry grew in Nagoya Port, which lead 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. Regardless, on 25 to 26 September 1921, a typhoon struck and broke several areas of the Shin-Horikawa riverbank. 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 26 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.

This 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.

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 backward up rivers and canals and over collapsed levees, which further expanded the flooded area of the inland city. Since the Nagoya area was largely developed for manufacturing, the removed groundwater by manufacturing firms caused serious land subsidence. 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 were released 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).

The large damage in Nagoya City as a result of the supertyphoon can also be considered a man-made disaster to some extent, instead of a natural disaster. More precisely, in those days, central and local government policies for disaster prevention were not sufficient in that residents did not have enough knowledge about typhoons and the related high tides. Furthermore, the electricity blackout during the typhoon meant that people could not use their radio, so no public typhoon information was available, which likely reduced Nagoya City residents' cautiousness and deterred evacuation (Central Disaster Management Council, 2008).

After the supertyphoon, the government spent considerable amounts of money on post-disaster aid and the city's infrastructure was repaired quickly. For example, all railways and main roads resumed operation at the latest by the end of November 1959, i.e., a few months after the event (Architectural Institute of Japan, 1961). Due to this investment (see Figure 1), Nagoya City's population did not drop substantially after the typhoon but continued growing. The recovery of the economy also appears to have been surprisingly fast. More precisely, by November 1959, the level of manufacturing output was already again at pre-typhoon levels (Nagoya City, 2012). The manufacturing output and number of employees in Nagoya City have increased steadily without any visible interruption after the Ise Bay Typhoon (Figure 2).

The raw aggregate data shown in Figures 1 and 2 suggest that while the damage from the supertyphoon was huge, it did not have any long-term effect in that the economy appears to have recovered quickly. However, damage and recovery processes may nevertheless differ across firms as well as industries. 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. Manufacturing firms, in particular large ones, are believed to have experienced relatively small direct damage. 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. However, the indirect damage was likely to have been much more crucial in that many manufacturing workers could not return to their workplaces due to their seriously damaged residences; thus, firms could not avoid reducing their labour force in the long run. They also reduced their output due to the damage experience by affiliate firms (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. Nevertheless, 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 because the local government explicitly supervised the market and police seized illegal commercial transactions (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*, 28 September and 5 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 Damage Data

To proxy for local damages within Nagoya City due to storm surges after the supertyphoon, we use a map of the number of days flooded at the Chomé level, which is the minimum level of administrative 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 shape (Figure 3). As can be seen, there is considerable heterogeneity of the inundation days across the city, 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.

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 are annually published by Teikoku Koushinjo Co., Ltd. Although the data were published annually from the 1910s to 1930s, the company stopped publication during the war period and only restarted in the late 1950s. The data cover all companies with capital assets over 1 million yen as well as all banks and credit co-operatives in Japan, i.e., not only manufacturing industries, but also services including wholesale and retail sectors, among other miscellaneous sectors (e.g., construction, public utilities, transportation services). Here we exclude the banking and financial sector. The data include information on firm's location, year of founding, employees, sales, capital assets and sector of production. 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 and period, we collated the data for the years 1958 and 1960, where information on firms was collected in November and September of those years, respectively. We thus have snapshots of the populations of firms (with capital assets over 1 million yen) in the year immediately prior and the year immediately after the supertyphoon. Our analysis is thus limited to capturing only any short-term impact of the supertyphoon. In the existing studies using firm-level data, however, this always has been the case even though the time period was always for a much more recent period. Furthermore, since the damage caused by the supertyphoon in Nagoya City was fairly short-run as mentioned above, this is not a critical issue.

We show the distribution of firms by Chomé in Figure 4. Accordingly, there is no even 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 a large variation in the number of enterprises even within the Chomés that contain firms, ranging from 1 to 103.

[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 is mainly an agricultural area.

3.3 Summary Statistics

Table 2 provides the summary statistics for all our variables. As can be seen, there is considerable variation across all characteristics. In particular, firm size ranged from between 98 employees to over 10,000 employees and between just having started operation and having operated for 68 years. Growth over the period right before and immediately after the supertyphoon ranged widely across sales, employment, labour productivity and capital sectors. About 11% of the firms in our sample closed down over the three-year period focused on in this study. Importantly, the number of days flooded due to the supertyphoon ranged from being non-affected to 25 days, where the standard deviation of 1.4 suggests considerable variation around the mean number of flooded days.

4. Econometric Analysis

4.1 Econometric Specification

Our main goal is to investigate how the flooding due to storm surges caused by the Ise Bay Typhoon impacted the firms' probability of survival and the performance of survivors. In particular, we estimate a probit model for survival:

$$\mathrm{Prob}(\mathrm{SURVIVAL}_{it}) = \Phi(\beta_0+\beta_1\mathrm{FLOOD\_DAYS}_{it}+\beta_2\log(\mathrm{SALES}_{it-1})+\beta_3\log(\mathrm{EMP}_{it-1})+ \beta_4\log(\mathrm{CAPITAL}_{it-1})+\beta_5\mathrm{AGE}_{it-1}+\varepsilon_i) \quad (1)$$

where $\mathrm{SURVIVAL}_{it}$ is an indicator variable that takes on the value of 1 if firm *i* still exists after the typhoon (at time *t*), FLOOD_DAYS is the number of days that the Chomé that firm *i* is located in was flooded, and total sales (SALES), firm size measured by total employees (EMP), capital asset (CAPITAL) and firm age (AGE) are controls of firm *i* measured before the typhoon struck, i.e., at t-1.

We use the following econometric linear model to quantify the survivors' performance:

$$\Delta\log(Y_{it-1\rightarrow t})=\beta_0+\beta_1\mathrm{FLOOD\_DAYS}_{it}+\beta_2\log(\mathrm{SALES}_{it-1})+\beta_3\log(\mathrm{EMP}_{it-1})+\beta_4\log(\mathrm{CAPITAL}_{it-1}) +\beta_5\mathrm{AGE}_{it-1}+\varepsilon_i \quad (2)$$

where $\Delta\log(Y_{t-1\rightarrow t})$ is the growth rate of a number of performance indicators, i.e., SALES, EMP, SALES/EMP and CAPITAL. The control variables are as in (1).

For both (1) and (2), an important aspect to consider is how to calculate the standard errors, given that the flood variable will be correlated across firms both within and across Chomés, and not considering this could lead to a downward bias for the FLOOD_DAYS estimate. As noted by Schlenker and Roberts (2009) and Hsiang (2010, 2016), this may be particularly a problem when examining the effect of climatic phenomena, which are likely to be spatially correlated. These researchers suggest modelling this spatial dependence explicitly. The choice to make is how far this spatial correlation reaches. Given that we want to allow for the most extensive correlation as possible, we set the spatial correlation matrix to the largest distance between Chomés for each sample in our regression and adjust the standard errors accordingly in the spirit of Hsiang (2016).

4.2 Results

The results from our probit model of survival are given in Table 3. As can be seen in the first column, firm survival, at least immediately after the supertyphoon, was unaffected by the flooding in our total sample. This is also true for our three sectoral sub-samples, i.e., manufacturing (MANUF) in the second column of Table 3, retail and wholesale (RETAIL) in the third column and the miscellaneous sectors (MISC) in the fourth column. The miscellaneous sectors are composed of construction, mining, public utilities, transportation services, real estate and amusement industries. Importantly though, around 70% of the miscellaneous sector in our sample is categorized as construction-related industries (e.g., construction, construction materials, plumbers, electricians, repairmen, civil engineering). Thus, any results can be primarily interpreted in terms of the construction sector. In terms of our controls, the factors that can predict firm survival differ across the total and the sectoral sub-samples. More specifically, firms that sold more before the supertyphoon where overall more likely to survive, and this holds for the total sample as well as for the retail and wholesale sector and the remaining sectors. Similarly, while age—the significant predictor of firm survival for the total sample—acts to decrease the likelihood of exit, this is only true for the manufacturing sector. This age effect is consistent with previous studies (e.g., Cole et al. 2019).[6] Finally, prior capital and employment act to reduce firm survival, albeit only for the miscellaneous industries. Smaller firms in the miscellaneous industries, if measured in terms of employment, are also more likely to survive.

[6] Cole et al. (2019) performs survival analysis in manufacturing firms after the 1995 Kobe Earthquake and find that firm age had a positive impact on survival.

In examining the growth performance of all survivors (see Table 4), the prior sales, employment, capital and age are all observed to act as significant predictors. More importantly, we find that the greater the number of days that the Chomé in which the firm operated was flooded tends to reduce sales and employment growth rates but increases the capital growth rate. By contrast, there is no impact on labour productivity (SALES/EMP), although this may not be surprising given that both output and employment are reduced by the flooding. Taken at face value, an additional day of flooding caused capital growth to rise for survivors by 0.2%, while employment and sales growth fell by 0.1 and 0.2%, respectively. This estimation result implies that the damage from the supertyphoon reduced sales and employment growth but led to renewed machines and factory buildings.

Considerable heterogeneity is observed in the sectoral sub-samples (Tables 5–7). While generally most control variables are predictors of growth, these can differ in size and sign. Specifically, our focus is on the number of flood days. First of all, the result for the manufacturing sector (Table 5) shows that the number of flood days lead to a reduction in employment growth and a rise in capital growth, albeit with no impact on sales. The fall in employment growth without a corresponding rise in sales translates into an average rise in labour productivity growth for manufacturing firms due to the storm surge. Next, the results for the retail and wholesale sectors (Table 6) show that sales were unaffected, but employment rose, and consequently labour productivity also fell. Firms in this industry also simultaneously reduced their capital growth. Finally, in terms of the remaining miscellaneous industries, which are mainly construction firms (Table 7), their sales growth and labour productivity fell, while employment growth rose, but capital was unaffected. The quantitative effects in the miscellaneous sector appear to be much larger than for the other two industries. For instance, employment in the miscellaneous sector rose by 1.3% compared to 0.6% in the retail and wholesale sector. The absolute effect on labour productivity is also much larger in the miscellaneous industries (2.4%) than the corresponding impacts in the other two sectors.

Our findings could be interpreted as follows. As mentioned in the previous section, infrastructure such as roads and railways were repaired quickly, and many barracks were built within only a few months after the supertyphoon. This construction boom is likely to have required a large number of workers in the short term and the surge in construction demand likely drives employment growth in the miscellaneous industries, i.e., mainly the construction industry. In contrast, Nagoya City's manufacturing sector faced a serious labour shortage because many workers could not commute to their workplace (Central Disaster Management Council, 2008). This labour reallocation from other sectors to the construction sector is observed frequently

(Kirchberger, 2017).[7] Many manufacturing factories temporarily stopped operation and simultaneously replaced inundated machines and factory facilities with new ones. 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; Okazaki et al., 2019).[8] According to this creative destruction, although there is the destruction of physical and human capital, natural disasters offer opportunities to upgrade technologies and production techniques. Thus, this could explain why we find that the impact of flooding on employment growth in the manufacturing sector is negative but positive for capital growth. This may also mean that the firms have used this opportunity to increase their labour productivity by replacing the missing workers with newer machines. Finally, for the retail and wholesale sector, many small retailers were located in the centre of Nagoya City, where several large-scale shopping streets were sited. As shown in Collier and Babich (2019), small firms were the most credit-constrained after the natural disaster. Thus, the supertyphoon severely damaged several of these big shopping streets and it would be difficult to recover from this damage due to a lack of financial access. As a consequence, a law on the association of shopping streets (the Shopping District Promotion Cooperatives Act) was established in 1962 to provide financial support to retailers after disaster (All Japan Association of Shopping Districts, 1962). In parallel, our results reveal that capital growth is negative in the flooded area in the retail and wholesale sector.

5. Conclusion

In this paper, we investigated the short-run heterogeneous 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 after the event as well as a localized damage index based on a historical flood inundation map show that the flooding caused by the supertyphoon did not cause firms to go out of business. However, firms did in general reduce both their sales and employment growth as a consequence of the flooding. Nevertheless, their capital growth also simultaneously increased as a consequence, suggesting that the supertyphoon might have been used as an

[7] Kirchberger (2017) found that the labour force shifted from the agricultural sector to the construction sector following an earthquake in Indonesia.

[8] A number of theoretical studies have explored creative destruction after a natural disaster (Okuyama, 2004; Hallegatte and Dumas, 2008). However, few studies investigated empirically. Pereira (2009) and Imaizumi et al. (2016) found 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 the growth of machine qualities in manufacturing firms after the 1923 Great Kanto Earthquake in Tokyo.

opportunity to upgrade capital. Decomposing our sample into enterprises working in manufacturing, wholesale and retail and other sectors (mainly construction), reveals considerable sectoral heterogeneity. More specifically, manufacturing firms actually did not reduce their sales growth after their flooding in any significant manner, but decreased employment while at the same time increasing capital growth. Thus, their overall labour productivity increased by replacing employment with machines. In stark contrast, while sales also did not decrease for firms in the wholesale and retail sector, they traded off capital growth with employment, which overall decreased labour productivity. The overall observed drop in sales thus came from firms in miscellaneous sectors, as confirmed by our results, where these businesses increased employment growth, and thus also experiencing a drop in labour productivity growth.

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, as proxied by the number of days flooded. As noted earlier, 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 non-direct effects, leading to a downward bias in our estimates. Somewhat related to this finding, given that we only look at performance one year after the event, any sales reduction, compositional input changes and hence labour productivity impacts may have not lasted beyond the short-term window of our analysis.

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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

	Mean	Std.Dev.	Min.	Max.
FLOOD_DAYS	1.4	3.8	0	25
SURVIVAL	0.89	0.310	0	1
$\Delta\log(SALES_{t-1\rightarrow t})$	0.18	0.45	-6.50	5.01
$\Delta\log(EMPL_{t-1\rightarrow t})$	0.18	0.37	-2.05	5.46
$\Delta\log(SALES/EMP_{t-1\rightarrow t})$	-0.003	0.502	-6.689	4.779
$\Delta\log(CAPITAL_{t-1\rightarrow t})$	0.21	0.41	-2.30	3.58
$SALES_{t-1}$	57242	495618	200	2.00e+7
EMP_{t-1}	98	382	2	10040
$SALES/EMP_{t-1}$	6.13	1.20	0.14	13.15
$CAPITAL_{t-1}$	2987	422194	50	1800000
AGE_{t-1}	10	8	0	68

Table 3: Firm Survival

	(1)	(2)	(3)	(4)
FLOOD_DAYS	0.00127	0.00647	-0.00993	0.0106
	(0.0125)	(0.0167)	(0.0286)	(0.0286)
$\log(SALES_{t-1})$	0.228***	0.0779	0.294***	1.092***
	(0.0562)	(0.0831)	(0.0820)	(0.408)
$\log(EMP_{t-1})$	0.0422	-0.00797	0.105	-0.374*
	(0.0552)	(0.0830)	(0.0833)	(0.206)
$\log(CAPITAL_{t-1})$	-0.0536	0.00904	-0.0701	-0.394**
	(0.0535)	(0.0780)	(0.0804)	(0.192)
AGE_{t-1}	0.0158**	0.0227**	0.0143	0.0144
	(0.00719)	(0.0110)	(0.0106)	(0.0153)
SAMPLE	ALL	MANUF	RETAIL	MISC
Observations	2,061	741	1,118	154
PseudoR2	0.0541	0.0365	0.0666	0.342

Notes: (i) Robust standard errors in parentheses; (ii) *** p<0.01, ** p<0.05, * p<0.1; (iii) Ward and sector dummies included.

Table 4: Performance of Survivors – All

	(1)	(2)	(3)	(4)
Dep. Var.:	Δlog(SALES$_{t-1\rightarrow t}$)	Δlog(EMPL$_{t-1\rightarrow t}$)	Δlog(SALES/EMP$_{t-1\rightarrow t}$)	Δlog(CAPITAL$_{t-1\rightarrow t}$)
FLOOD	-0.00245***	-0.00148*	-0.000970	0.00231***
	(0.000904)	(0.000841)	(0.000814)	(0.000764)
log(SALES$_{t-1}$)	-0.180***	0.00669***	-0.187***	0.0685***
	(0.0108)	(0.00185)	(0.0109)	(0.00477)
log(EMP$_{t-1}$)	0.0754***	0.0373***	0.0381***	-0.115***
	(0.00705)	(0.00350)	(0.00897)	(0.00565)
log(CAPITAL$_{t-1}$)	0.0879***	-0.0633***	0.151***	0.103***
	(0.00607)	(0.00424)	(0.00866)	(0.00588)
AGE$_{t-1}$	-0.00478***	-0.00303***	-0.00175**	-0.00195***
	(0.000719)	(0.000220)	(0.000717)	(0.000395)
Observations	1,844	1,844	1,844	1,844
PseudoR2	0.233	0.230	0.127	0.275

Notes: (i) Spatial dependence corrected standard errors in parentheses.; (ii) *** p<0.01, ** p<0.05, * p<0.1; (iii) Ward and sector dummies included.

Table 5: Performance of Survivors – Manufacturing

	(1)	(2)	(3)	(4)
Dep. Var.:	Δlog(SALES$_{t-1\rightarrow t}$)	Δlog(EMPL $_{t-1\rightarrow t}$)	Δlog(SALES/EMP $_{t-1\rightarrow t}$)	Δlog(CAPITAL $_{t-1\rightarrow t}$)
FLOOD_DAYS	-0.000404	-0.00496***	0.00456***	0.00530***
	(0.00153)	(0.00104)	(0.000975)	(0.000773)
log(SALES $_{t-1}$)	-0.173***	0.00712*	-0.181***	0.104***
	(0.0175)	(0.00363)	(0.0168)	(0.00890)
log(EMP $_{t-1}$)	0.0640***	0.0399***	0.0241**	-0.140***
	(0.00793)	(0.00559)	(0.0106)	(0.00685)
log(CAPITAL $_{t-1}$)	0.0864***	-0.0628***	0.149***	0.108***
	(0.0136)	(0.00982)	(0.0197)	(0.00911)
AGE $_{t-1}$	-0.00746***	-0.00439***	-0.00307***	-0.00216***
	(0.000849)	(0.000611)	(0.000713)	(0.000675)
Observations	655	655	655	655
PseudoR2	0.274	0.235	0.162	0.290

Notes: (i) Spatial dependence corrected standard errors in parentheses.; (ii) *** p<0.01, ** p<0.05, * p<0.1; (iii) Ward and sector dummies included.

Table 6: Performance of Survivors – Retail & Wholesale

	(1)	(2)	(3)	(4)
Dep. Var.:	Δlog(SALES$_{t-1\rightarrow t}$)	Δlog(EMPL $_{t-1\rightarrow t}$)	Δlog(SALES/EMP $_{t-1\rightarrow t}$)	Δlog(CAPITAL $_{t-1\rightarrow t}$)
FLOOD_DAYS	-0.00321	0.00577**	-0.00898***	-0.00559**
	(0.00235)	(0.00231)	(0.00329)	(0.00262)
log(SALES $_{t-1}$)	-0.195***	-0.00101	-0.194***	0.0524***
	(0.0201)	(0.00286)	(0.0207)	(0.00655)
log(EMP $_{t-1}$)	0.0971***	0.0321***	0.0650***	-0.101***
	(0.0128)	(0.00385)	(0.0139)	(0.00974)
log(CAPITAL $_{t-1}$)	0.0851***	-0.0462***	0.131***	0.0979***
	(0.00752)	(0.00458)	(0.00676)	(0.00700)
AGE $_{t-1}$	-0.00354***	-0.00259***	-0.000949	-0.00286***
	(0.000857)	(0.000315)	(0.000877)	(0.000684)
Observations	1,026	1,026	1,026	1,026
PseudoR2	0.229	0.233	0.118	0.263

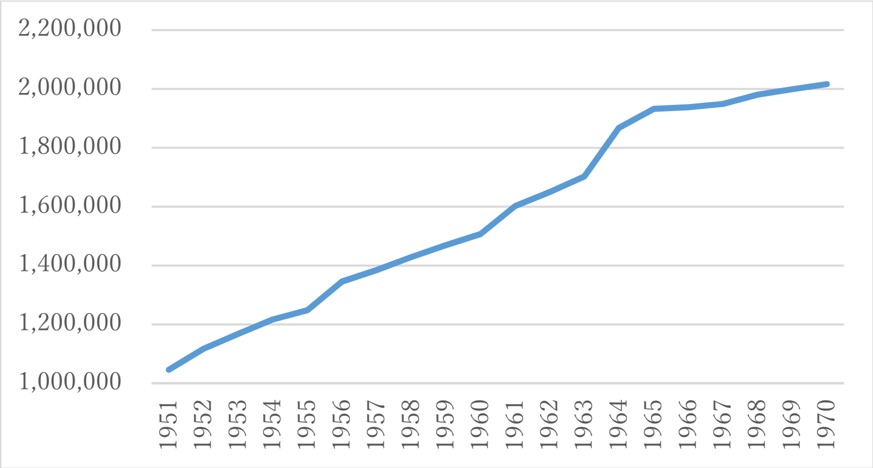
Notes: (i) Spatial dependence corrected standard errors in parentheses.; (ii) *** p<0.01, ** p<0.05, * p<0.1; (iii) Ward and sector dummies included.

Table 7: Performance of Survivors – Miscellaneous

	(1)	(2)	(3)	(4)
Dep. Var.:	Δlog(SALES$_{t-1\rightarrow t}$)	Δlog(EMPL $_{t-1\rightarrow t}$)	Δlog(SALES/EMP $_{t-1\rightarrow t}$)	Δlog(CAPITAL $_{t-1\rightarrow t}$)
FLOOD_DAYS	-0.0105***	0.0131***	-0.0235***	0.00406
	(0.00342)	(0.00141)	(0.00340)	(0.00293)
log(SALES $_{t-1}$)	-0.129***	0.118***	-0.247***	0.0500***
	(0.0108)	(0.00889)	(0.0133)	(0.0160)
log(EMP $_{t-1}$)	0.0289***	0.0615***	-0.0326**	-0.0871***
	(0.0108)	(0.00805)	(0.0139)	(0.0128)
log(CAPITAL $_{t-1}$)	0.116***	-0.222***	0.338***	0.0927***
	(0.0139)	(0.0218)	(0.0194)	(0.0133)
AGE $_{t-1}$	0.000615	0.00249***	-0.00188	0.00213
	(0.00143)	(0.000706)	(0.00171)	(0.00146)
Observations	163	163	163	163
PseudoR2	0.350	0.351	0.279	0.408

Notes: (i) Spatial dependence corrected standard errors in parentheses.; (ii) *** p<0.01, ** p<0.05, * p<0.1; (iii) Ward and sector dummies included.

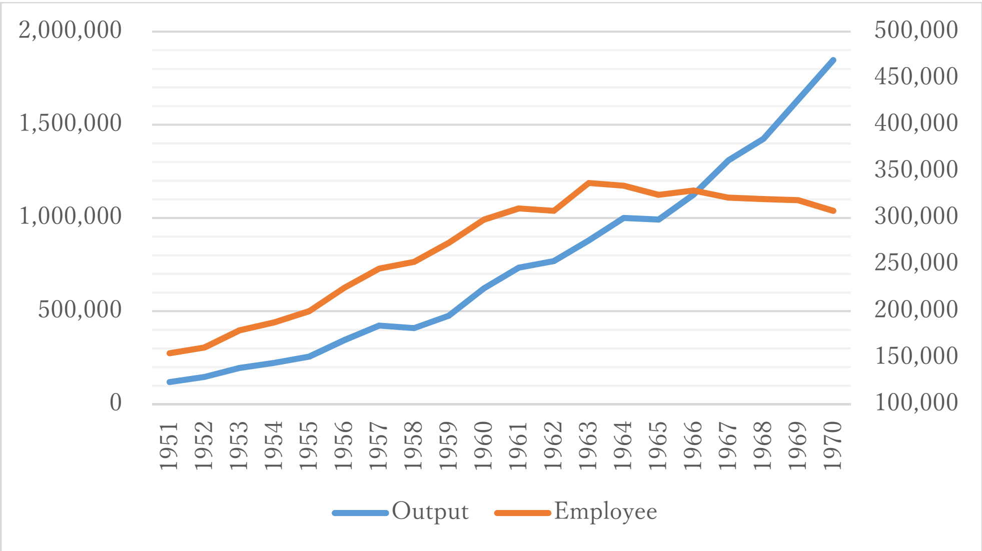
Figure 1: Population in Nagoya City



Source: Nagoya city (1989)

Figure 2: Manufacturing Output and Employees in Nagoya City

Output (left scale, unit: yen) and employees (right scale, unit: person)



Source: Nagoya city (1989)

Figure 3: Storm Surge Flooding – Number of Days Flooded

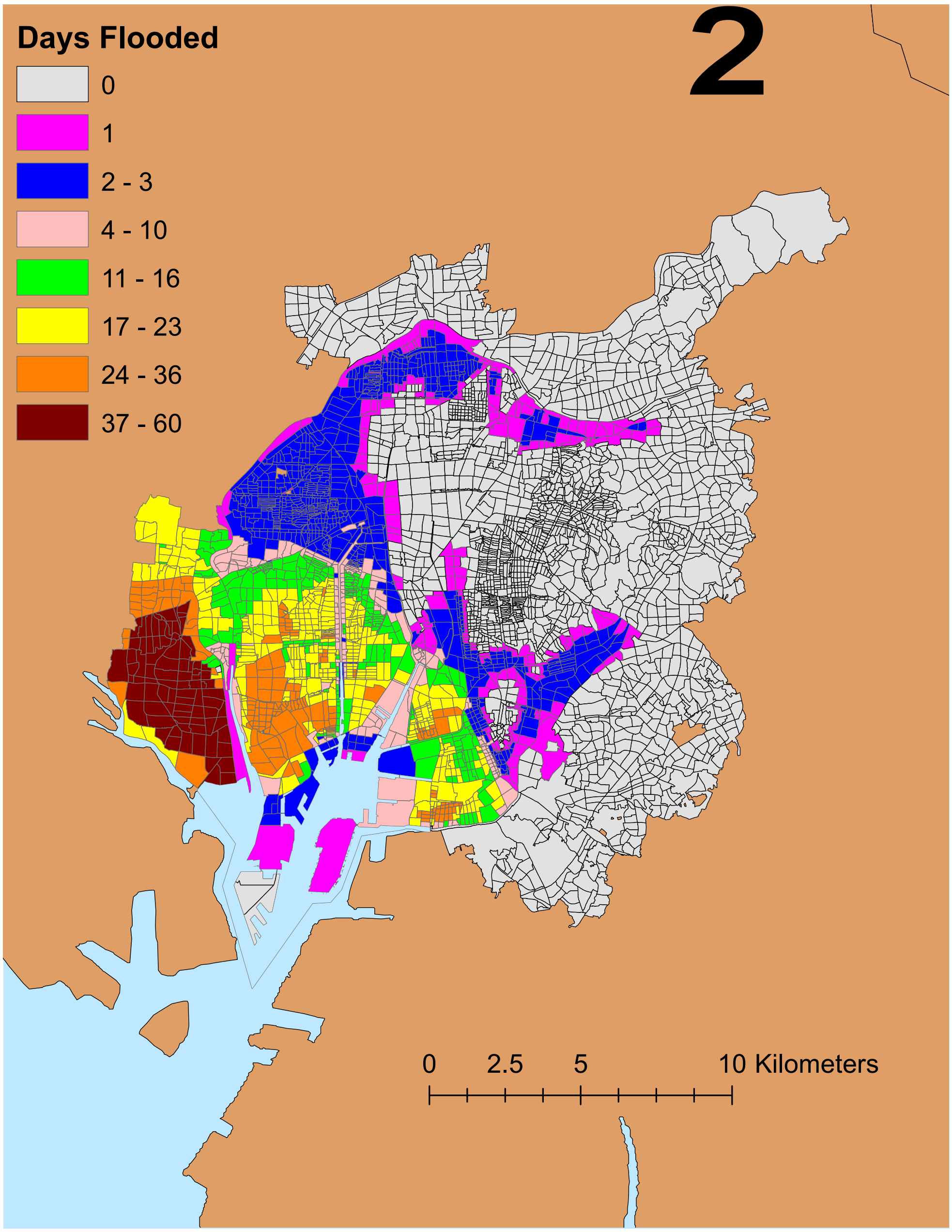


Figure 4: Storm Surge Flooding – Number of Firms in Sample