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Abstract

The Great Kanto Earthquake occurred on September 1st, 1923 and inflicted serious damage on Yokohama City as well as Tokyo City. For example, about 90% of the factories in Yokohama City were burnt down. However, these manufacturing industries appear to have recovered from the damage swiftly. This paper investigates the existence of creative destruction due to the Great Kanto Earthquake. Using firm-level data on capital (horsepower of motors) before and after the earthquake, we find substantial creative destruction in Yokohama city. Larger firms tend to increase their capital more in seriously damaged areas.

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The Great Kanto Earthquake occurred on September 1st, 1923 and inflicted serious damage on Yokohama City as well as Tokyo City. For example, about 90% of the factories in Yokohama City were burnt down. However, these manufacturing industries appear to have recovered from the damage swiftly. This paper investigates the existence of creative destruction due to the Great Kanto Earthquake. Using firm-level data on capital (horsepower of motors) before and after the earthquake, we find substantial creative destruction in Yokohama city. Larger firms tend to increase their capital more in seriously damaged areas.

Keywords: natural disaster, creative destruction, capital, damage index, Great Kanto Earthquake

JEL classification: N95, N85,Q54, R11

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1. Introduction

Large natural disasters sometimes have substantial and persistent impacts on economies. For example, the Lisbon Earthquake in 1755 not only changed prices and wages, but also led to a policy reform toward mercantilist type policies, and thereby improved the long-run performance of the Portuguese economy (Pereira, 2009). For Japan, the Great Kanto Earthquake in 1923 changed the spatial distribution of industries and resulted in the development of a new industrial agglomeration (Imaizumi, et al. 2016). Thus, while the Lisbon Earthquake and the Great Kanto Earthquake were very damaging disasters, they also arguably had positive long-run impacts on the economies.

Positive long-run impacts of natural disasters have been extensively studied in economics over the last decade. Much of the work in this regard has tried to disentangle the two countervailing forces of natural disasters. On the one hand, there is the destruction of physical and human capital and the inherent negative disruptions to normal economic activity. On the other hand, natural disasters offer opportunities to upgrade technologies and production techniques that may have otherwise been retained for substantially longer. This latter consequence arguably falls within a process that was originally coined by Schumpeter (1942) as 'creative destruction' (pp.82–85).[1]

The possibility of creative destruction provides a new perspective in the historical research on the implications of natural disasters. As noted above, the Great Kanto Earthquake caused a shift in the spatial distribution of industries. However, while this

[1] There are a number of theoretical studies on creative destruction and the conditions that may lead to creative destruction after a natural disaster. See for instance, Okuyama (2004) and Hallegatte and Dumas (2008).

location shift may have also involved the upgrading of factories and equipment, this issue has, to the best of our knowledge, not yet been explored in the economic history literature. Hence, this paper investigates the possibility of creative destruction at the industry-level and the firm-level. That is, we investigate the implications of the damage by the Great Kanto Earthquake for the growth of industries and firms after the disaster.

After World War I, the Japanese economy was struggling to upgrade industrial structure under harsh international competition and prolonged depression. Also, the Japanese economy in this period was characterized by the emergence of the "dual structure" between large firms and small- and medium-sized enterprises (Nakamura 1983; Flath 2005). We examine whether creative destruction by the earthquake really existed and, if it did, what implications it had on the evolution of the Japanese economy.

This paper also contributes to the literature on creative destruction after natural disasters in economics. In this regard, despite a large body of literature on this topic, the evidence is at best mixed, with most studies finding, if anything, small negative effects, although a handful also finds some small positive effects.[2] In terms of existing firm-level studies, there are hints at the possibility of some creative destruction. For instance, Leiter et al. (2009) find that European firm employment growth is higher in regions that experienced major floods. In a study of Japanese manufacturing firms after the 1995 Kobe Earthquake, Cole et al. (2013) provide evidence that labor productivity increased in surviving firms after the disaster. Importantly, however, neither of these studies has a direct measure of technology or change in production processes and can

[2] As noted by Noy and duPont IV (2016), evidence in favor of creative destruction are typically nuanced, and the possible long-run positive effects appear to be limited only to fairly moderate natural disasters in higher-income countries or regions.

only infer creative destruction. Thus, the case of the Great Kanto Earthquake allows us the opportunity to investigate whether natural disasters can indeed cause creative destruction. More precisely, because production processes during this period were less complex, we can clearly measure whether natural disasters have on some occasions led to an upgrading of production technologies and processes.

For the purpose of our study, we focus on manufacturing firms in Yokohama City, the largest port city close to Tokyo. This is because Yokohama City was very seriously damaged by the Great Kanto Earthquake as we state below, and detailed data are available.

2. Damages to and Recovery of the Industries in Yokohama City

2.1 Background

Yokohama City is located to the south of Tokyo and is one of the oldest port cities in Japan (Figure 1). It currently has the second largest population in Japan (3.6 million people).[3] From a historical viewpoint, Yokohama has played a crucial role in Japanese economic growth. More precisely, Japan had been an autarchic economy for more than 200 years but during the 1850s and 1860s experienced a drastic change to a free trade economy. In this regard, the US–Japan Treaty of Army and Commerce of 1858 forced Japan to trade with foreign countries and open several ports, Yokohama (Kanagawa) was one of the earliest ports to open.

As shown in Bernhofen and Brown (2005), Japan experienced a drastic change

[3] Nowadays Metropolitan Tokyo has 8.5 million populations. Yokohama City has expanded to the suburbs. Yokohama City was 39.27 square km until 1927. By integrating with surrounding villages and towns, the current size of Yokohama City is 400 square km since 1939. Yokohama is the capital city of Kanagawa Prefecture.

in economic structure after the opening of trade, in line with the principle of comparative advantage. This induced the formation of industrial clusters in the early stages of the Japanese economy. More specifically, Japan started exporting silk and tea in this early period, for which Yokohama served as the main port.[4] As shown in Figure 2, Yokohama was the largest port in Japanese exports over time. Until the Great Depression of 1929, Yokohama port largely increased export values. As such Yokohama was the center of a number of advanced industries: manufacturing firms, banking-financial sectors, wholesalers, retailers, trading companies, and transportation companies. Yokohama also had a major silk market and was connected via railways to central Tokyo. By 1920, Yokohama's population constituted 420,000 spread over 39.27 square km, and thus, at the time, was the sixth largest in Japan.[5] Due to its industrial development in the earlier stages, Yokohama also became the center of manufacturing clusters after the Industrial Revolution of the 1910s and 1920s.

Figure 1, Figure 2

2.2 Overview

On September 1st, 1923, a huge earthquake of magnitude 7.9 hit the center of Japan. The total number of dead and missing is estimated to be over 100,000, and the destruction of assets is believed to be around 35% of Japan's GNP in 1922 (Imaizumi, et al. 2016). Indeed, it was the most serious natural disaster that Japan had experienced up to the present date. Table 1 summarizes the damage by prefecture. The damage was

[4] See Yamazawa and Yamamoto (1979) for more details on early Japanese trade. Arimoto et al. (2014) conducts econometric analysis on the silk sector and industrial development.
[5] In 1920 Tokyo city had a population of 2 million people and 81.24 square km and Osaka, the second largest city, had a population of 1 million.

concentrated in two prefectures, Tokyo and Kanagawa. While the damage in Tokyo Prefecture, especially in Tokyo City, has been widely publicized, the scale of the damage in Yokohama City in Kanagawa Prefecture, when standardized by the population and the number of buildings, was larger than in Tokyo City. In Yokohama City, 5.23% of the people were dead or missing, and 73.2% of the buildings were destroyed completely or burnt (Table 1), whereas, in Tokyo City, 3.03% of the people were dead or missing and 63.2% of the buildings were destroyed completely or burnt (Table 1).

Table 1

The earthquake caused serious damage to several industries in Yokohama. In this regard, Yokohama City Office conducted a survey just after the earthquake of the damage to the city's manufacturing factories with 20 or more employees. As shown in Table 2, around 90% of the manufacturing factories were burnt down. The seriousness of the damage to manufacturing industries can also be observed in the time series data of Figure 3, where the number of factories and workers declined sharply from 1921 to 1923.[6] At the same time, it is also notable that after the sharp decline, the numbers of manufacturing factories and workers recovered swiftly. In 1924 and 1927, the numbers of manufacturing factories and workers exceeded the numbers in 1921, respectively.

Table 2, Figure 3

The damage to 38 individual manufacturing factories and their recovery at the

[6] Data for 1923 were not collected due to the earthquake.

end of 1924 to early 1925 are outlined in Yokohama City Office ed. (1926) (pp.399–413). Accordingly, there was a large variation in the extent of damage and recovery. On the one hand, some factories sustained serious damage and continued to be closed. For example, Japan Veneer Lumbering Co. (*Nihon Benia Seizai*) was not re-opened but instead requested government aid. The Yokokama Spinning Co. (*Yokohama Boseki*) factory was destroyed and was obliged to remain closed. On the other hand, other factories did not experience substantial damage. At Japan Optical Instrument Co. (*Nihon Koki Kogyo*), while a small part of the factory building and equipment was destroyed and damaged, the production capacity was not compromised and it continued operation.

What is remarkable for the context of this paper is that some factories that incurred serious damage overcame these damages and used the shock to undertake new steps of development. For example, almost the whole of the Yokohama Cable Plant (*Yokohama Densen Seizoussho*) of Furukawa Electric Co. (*Furukawa Denki Kogyo*) was burnt down but it was anticipated that once the reconstruction work was completed the plant would be larger than before the earthquake. Also, *Makuzu Gomei*, a ceramic company, lost its plant, but constructed a new plant, and began the construction of a new ideal kiln (ascending kiln). In the next subsection, we will further discuss the cases of Furukawa Electric Co. and Kirin Brewery Co. (Kirin Beer) and Ford Motors of Japan, for which more detailed information is available.

2.3 The cases of Furukawa Electric Co., Kirin Brewery Co., and the Ford Motor Company of Japan Co.

Furukawa Electric Co. was a major cable company in Japan, owned by Furukawa

Zaibatsu, one of the 10 largest *Zaibatsu* groups (Holding Companies Liquidation Committee 1950, pp.415–417). The origin of the Furukawa family's businesses was in copper mining and refining at the Ashio Mine, but later their businesses were extended to copper processing. In 1908, Furukawa Zaibatsu acquired Yokohama Cable Co., a major company of covered wire. In 1920, the company was renamed the Furukawa Electric Co., merging two of the Furukawa Zaibatsu cable plants (the Nikko Plant in Tochigi Prefecture and the Honjo Plant in Tokyo Prefecture). Furukawa Electric also managed other cable companies affiliated to Furukawa Zaibatsu (Furukawa Electric Co., 1991, pp.150–151).

The Great Kanto Earthquake caused serious damage to its Yokohama and Honjo plants. This damage was reflected in the decline in the value of fixed assets in the second half of 1923, as shown in Figure 4. By early 1924, Furukawa Electric decided on a plan of reconstruction. The plan included a drastic restructuring and reallocation of cable production in Furukawa Zaibatsu. That is, the Yokohama Plant specialized in *high-quality* cable, while the Nikko Plant and affiliated companies specialized in *lower-quality* cable. In reconstructing the Yokohama Plant, they purchased new land and reformed the layout of the buildings, so that the whole plant could be managed more efficiently (Furukawa Electric Co., 1991, pp.150–151). In contrast, the Honjo Plant was closed.[7] The business report of Furukawa Electric stated, "In reconstructing the damaged plants, we are not only recovering them but also completely improving the

[7] The Great Kanto Earthquake had a persistent impact on the spatial distribution of industries around Tokyo. While the industrial agglomeration in the eastern part of Tokyo City including Honjo Ward relatively declined, a new industrial agglomeration developed in the southwestern part of Tokyo (Imaizumi, et al. 2016). The closure of Honjo Plant and the reconstruction of the Yokohama Plant by Furukawa Electric is a typical case of this shift of industrial agglomeration.

equipment, with the idea of turning misfortune into good account."[8] As shown in Figure 4, its fixed assets and sales recovered and exceeded the level before the earthquake. Meanwhile, the return on asset (ROA) was stable, although not so high.

Figure 4

Kirin Brewery Co. was founded in 1907 and acquired The Japan Brewery Co., the oldest beer company in Japan, located in the Yamate area of Yokohama City (Kirin Brewery Co. 1957, p. 55). The Yamate area is in the eastern part of Yokohama City and was a foreign concession until 1899 when the partial treaties between Japan and the Western countries were revised. The First World War provided a great opportunity for the Japanese beer industry to develop as in other sectors that had imported products from Europe. In this regard, Kirin Brewery constructed a new plant in Hyogo Prefecture (Kanzaki Plant), in addition to the original Yokohama Yamate Plant. In May 1923, Kirin Brewery acquired Toyo Brewery Co. to add Sendai Plant in Miyagi Prefecture to its production capacity.

However, just after the acquisition of Toyo Brewery Co., the Great Kanto Earthquake hit Kirin Brewery's headquarters and the Yokohama Yamate Plant. Yokohama Yamate Plant and the headquarter were almost destroyed completely. The original reconstruction plans revealed that the cost of repairing the plant was nearly as large as constructing a new plant. In addition, since before the earthquake, it was known that the site of the Yokohama Yamate Plant did not have enough room for future expansion, and its location was characterized by other inconveniences. Hence, Kirin

[8] Furukawa Electric Co., *Business Report* (*Eigyo Hokokusho*), December 1923, p.7.

Brewery decided to move Yokohama Plant from Yamate to the Namamugi area, which is in the northeastern part of Yokohama City. In this regard, Kirin Brewery (1957) notes that this relocation was an important step for the development of the company:

> "*Although it is true that the destruction of Yokohama Yamate Plant was a serious damage to the company, in another perspective this disaster promoted the construction of a new plant with brand new equipment, and thereby resolved the problems of transportation and water supply which we had been long suffering from, and, in turn, has been the basis of the present prosperity. In this sense, looking back, we can say that the benefit from the disaster much more than covered the loss.*" (pp.91–92)

Figure 5 summarizes the damage to Kirin Brewery and its recovery. In order to separate the impact of the earthquake from the effect of the acquisition of Toyo Brewery Co., which took place in the same year, we aggregated the data of Kirin Brewery and Toyo Brewery before the acquisition. Also, as the sales of beer have substantial seasonality, the sales data are depicted as centralized moving averages for two half-years. As can be seen in congruence with the earthquake event, the fixed assets and ROA declined sharply in the second half of 1923. The sales began to decline during this period. However, the fixed assets increased rapidly from 1924 and by 1926 became twice the size than before the earthquake. Meanwhile, sales also increased in the late 1920s. This reflects the completion of the new Yokohama Plant in 1926, which introduced equipment from the most advanced Western technology, especially the bottling equipment (Kirin Brewery Co. 1957, pp.104).

Figure 5

The Great Kanto Earthquake also heralded the start of a new industry in Yokohama. The automobile industry in Japan dates back to 1907 when Tokyo Jidosha Seisakusho produced a gasoline automobile. However, the industry did not grow substantially after that, although the Army tried to promote the industry with the Military Vehicle Support Law (*Gun-yo Jidosha Hojo Ho* in Japanese) in 1918 (Shinomiya 1998, pp.27–28, p.32; Yokota 1944, pp.34–39). The earthquake provided the Japanese automobile industry a springboard. Because railway networks in Tokyo City were seriously damaged, 1,000 cars were imported from the Ford Motor Co. The use of cars after the Earthquake made Japanese people recognize their usefulness. Ford Motors viewed Japan as a promising market and sent a mission to Japan in 1924 (Shimomiya 1998, pp.4–5). Based on the observations from the mission, Ford Motors decided to construct an assembly plant in Japan. They chose Yokohama as the location because it was close to the largest market, Tokyo, and had good access to ports and railways. In 1925 a temporary assembly plant was established, followed by a permanent large-scale plant in 1927, with advanced equipment including a conveyor system. Whereas, at first, this plant totally imported automobile parts from the U.S., it gradually increased the purchase of parts from suppliers in Japan, which stimulated development of related machinery and chemical industries around the plant (Yokohama City Office ed. 1971, p.473; Yokohama City Office ed. 1993, pp.476–477, 480).

3. Data

We use unique firm-level data for Yokohama City: *Handbook of Manufacturing Firms in Yokohama City* (*Yokohama-shi Kogyo Meikan*), by the Bureau of Manufacturing and Commerce of Yokohama City Office, (*Yokohama Shiyakusho, Shoukou-ka*).[9] Only the data for two years, 1921 and 1925, are available (as of the end of December, 1921 and 1925), but these conveniently cover only pre- and post-earthquake points in time. The dataset includes information on firm name, main product, address, owner's name, founding year, and horsepower of motors (if using motors). The coverage is all manufacturing sectors located in Yokohama City. Because there are no firm identifiers, firms are matched between two periods by using the information on firm address, firm name, founding year, and owner's name (in particular the family name).

Our earthquake damage data consists of *chome* (town district) level damage, taken from Takahama et al. (2001) and Omote (1949). More specifically, Takahama et al. (2001) used more than 150 historical documents and statistical records, while applying text-mining methods to interviews with 25 experienced individuals and local historians. Based on these historical sources and interviews, they then constructed chome level damage data for Yokohama City. The data include the total number of wood buildings and the number of buildings totally damaged and partially damaged at the chome-level. In addition, the original dataset of Takahama et al. (2001), not reported explicitly in their research paper, includes more detailed information on damage to roads and artificial areas at the chome-level.[10] Alternative damage data are taken from Omote

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[9] There are only a few cities (Tokyo and Osaka cities) that recorded similar firm lists and firm-level information as Yokohama city. However, Tokyo metropolitan city does not include any information on capital/machines in this pre- and post-earthquake period.

[10] Dr. Tsutomu Takahama (Kozo Keikaku Engineering Inc.) provided the original dataset.

(1949), who also constructed damage data at the chome-level based on 10 historical documents and statistical reports.

Figure 6 (Takahama et al., 2001) shows the damage map of Yokohama City, where each area represents a chome and the shading in the damage map shows the percentage of buildings totally destroyed. As can be seen, Yokohama City is a geographically concentrated area but is spatially heterogeneous in terms of damage. Noteworthy in this regard is that damage in Yokohama is fairly clustered in the central areas, where manufacturing industries were densely located. Based on Takahama et al. (2001), Figure 7 represents the histogram of damage at the chome-level, where the horizontal axis is the percentage of totally destroyed buildings. Accordingly, around 50% of chomes were damaged with more than 60% of buildings totally destroyed.

Figure 6, Figure 7

The summary statistics are reported in Appendix Table 1. Consistent with Figure 7, the mean of damage variables ("*Damage1(chome)*" and "*Damage(Omote)*" in the upper panel of the table) is between 0.3 and 0.5. This indicates that 30 to 50% of buildings were totally damaged on average at the chome-level. We measure firm's capital by the horsepower of motors in order to take into account the change in capital quality. Capital growth, given by the difference in the log of capital, between 1921 and 1925 is small but positive at the mean (0.2) in spite of substantial standard deviation (1.18). On average, the capital of manufacturing firms in Yokohama City grew slightly over the Great Kanto Earthquake.

We appreciate his and his coauthor's kindness.

4. Firm-level estimations

4.1 Capital growth

We first test whether seriously damaged firms were more likely to grow capital after the earthquake. To this end firm's growth rate of capital is regressed on its characteristics and chome-level building damage. More specifically, the following equation is estimated by ordinary least squares (OLS):

$$\text{Capital Growth}_{irs} = \beta_1 Cap_i + \beta_2 Damage_r + \beta_3 DamageCap_{ir} + \beta_4 X_i + \beta_5 Y_r + \mu_s + \varepsilon \quad (1)$$

where subscript *irs* indicates firm *i* in sector *s*, located in chome, *r*. *Capital Growth* is the growth of capital (horsepower) in firm *i* from 1921 to 1925 and *Cap* denotes capital (horsepower) of firm *i* in 1921.[11] *Damage* denotes our damage proxy of chome *r*. Two types of damage variables are employed. *Damage1(chome)* indicates the share of totally damaged buildings in total at chome *r*. The data is taken from Takahama et al., 2001. Alternatively, *Damage(Omote)* indicates Omote's (1949) damage index, which is the share of damaged buildings in total. *DamageXCap* is an interaction term of *Cap* and *Damage*, allowing for the possibility that more capital-intensive firms may be affected differently by the earthquake than their lesser counterparts. *Xi* is firm i's characteristics in 1921 while *Yr* is chome r's characteristics. μ_s is the sector dummy.

[11] The data of year 1921 does not include the number of employees. Thus, we cannot conduct employment growth. The information on employees is available only in 1925. By only using the data of year 1925, we conduct estimations on entry as shown below in the second column of Table 7 in section 4-3.

In terms of firm characteristics, *Xi*, we include a *Foreign_owner* dummy, as constructed from the nature of the owner's name, a *Relocation* dummy, which takes a value of one if a firm relocates to another place inside Yokohama city, and *Age* denotes a firm's age. The export specialization dummy, *Export*, takes unity if the main product name indicates "export only" in our data. In terms of chome characteristics, *Yr*, we employ the total number of buildings, a road damage dummy, and an artificial area dummy, which takes on the value of one if chome was constructed by a landfill in the Yokohama port. All the chome-level information is from Takahama et al. (2001).

Table 3 reports the results of estimating (1). Column 1 constitutes the simplest estimation without any firm and chome-level controls. As can be seen, *Damage* is significantly negative, while *Cap* is significantly negative. Thus, less capital-intensive firms tend to increase their capital. This can be interpreted as a mean reversion, but there was also a specific financial condition that encouraged capital accumulation for less capital-intensive firms.

More importantly, although our results indicate that in more damaged areas firm's capital tends to grow less, *DamageXCap*, which is of central interest in the current context, capital-intensive firms located in the damaged areas tend to experience a lower fall in capital intensity than less capital-intensive firms, as indicated by the significantly positive interaction term. We can use our coefficients to calculate the level of capital, *Cap*, above which a firm with an average level of damages, i.e., 0.316, would experience capital growth. The critical value implied by our coefficients is 1.731, which is above the mean level of *Cap* (0.936). This implies that an average firm with an average level of damage would nevertheless be subject to mean reversion of capital growth, although at a lower rate than if no earthquake had occurred. Alternatively, one could derive the level of damage needed for a firm with average capital to experience a net upgrading of machinery. In our data, this turns out to be 1.3922, and thus even if the area where the firm resides was completely damaged this would be not enough to induce capital growth if the firm is not large enough.

Table 3

Just after the Great Kanto Earthquake, the government and the Bank of Japan (BOJ) implemented a policy to supply abundant liquidity to the damaged areas. That is, the government legislated the emergency act prescribing that the bill payables issued in the damaged area and discounted before September 1st, would be rediscounted by the BOJ, and the government would compensate the losses of the BOJ incurred by this operation up to 100 million yen. Consequently, the BOJ rediscounted the bills of 431 million yen (Bank of Japan ed. 1983, pp.87–91), which was 2.89% of Japan's GNP in 1923. This large liquidity supply focusing on the damaged areas would have mitigated the financial constraints of damaged firms.

It is notable that this liquidity supply was mainly through the channel of banks. On the other hand, firms' access to banks substantially depended upon their sizes in prewar Japan. Teranishi (2011, p.293) showed that in Tokyo, Yokohama and Kobe City in 1932, the firms whose capital was less than 10,000 yen, borrowed more than 75% of their money from organizations and individuals other than banks,[12] and the firms with capital less than 10,000 yen accounted for 93.6% of the firm population in these three cities. This implies that smaller firms rarely enjoyed the effect of the liquidity supply

[12] See also Okazaki (2016).

policy.

Next, Column 2 includes the additional firm controls, i.e., the foreign ownership dummy, the relocation dummy, age and the exporter dummy. One finds that export specialization is a significantly positive determinant of capital growth, but firm age and relocation dummy are not significant. Reassuringly *Damage* and *Cap* remain significantly negative, while *DamageXCap* continues to significantly positive. Moreover, the size of the coefficients on these variables does not change much. Column 3 adds the chome-level variables, i.e., the total number of buildings, a road damage dummy, and artificially constructed area dummy. Here we find that only the total number of buildings is weakly positive. Therefore, even if we control firm characteristics and chome characteristics, all main results remain the same.

4.2 Survival of firms

This subsection investigates [1] firm survival, i.e., whether firms continued to operate, and [2] whether surviving firms switched their main product, as a consequence of the earthquake. For firm survival, we estimated the following probit model:

$$\text{Survival}_{irs} = \beta_1 Cap_i + \beta_2 Damage_r + \beta_3 DamageCap_{ir} + \beta_4 X_i + \beta_5 Y_r + \mu_s + \varepsilon \qquad (2)$$

where *Survival* is a dummy variable taking unity if firm *i* operates before and after the earthquake, and zero if the firm exits after the earthquake. The other controls are as in equation (1). Note that when a firm is recorded in the data of 1921 but not listed in 1925, the firm is regarded as having closed down.

Table 4 reports the estimations derived from equation (2). Accordingly, firms located in more damaged areas had a significantly reduced chance of survival for both damage proxies. Also, the interaction terms, *DamageXCap*, are all significantly positive in both columns, i.e. whether we use *Damage 1* or *Damage(Omote)*. This indicates that seriously damaged large capital firms are more likely to survive. In terms of the other controls, *Age* is significantly positive, which implies that older firms are more likely to survive. While the other variables also indicate that older firms are more likely to survive, they are less likely to survive in areas with more buildings and artificial areas.

The probit estimates show that the interaction of capital and damage is significantly positive. The marginal effect of the variable in the vector x on the probability of survival of the level x is written as $\frac{\partial \text{Survival}_{irs}}{\partial x_j} = \text{g}(\text{x}\beta)\beta_j$ where $\text{g}(\text{u}) = \text{dG}(\text{u})/\text{du}$. We can calculate the marginal effects of damage and capital on capital growth, keeping all other variables at the mean. The marginal increase in the interaction term of capital and damage raises the probability of survival by 0.4%.

Table 4

Next, we investigate a product switch after the earthquake. For this we estimate the following equation by a probit model:

$$\text{Switch}_{irs} = \beta_1 Cap_i + \beta_2 Damage_r + \beta_3 DamageCap_{ir} + \beta_4 X_i + \beta_5 Y_r + \mu_s + \varepsilon \qquad (3)$$

where *Switch* is a dummy variable indicating a product switch. If firm *i* switches its main product after the earthquake, the dummy takes the value of one, and zero otherwise. Table 5 reports the results. Accordingly, *Age* is significantly negative suggesting that younger firms are more likely to change main products, while the number of buildings at chome is significantly positive, which implies that firms in concentrated areas are more likely to switch products. However, except for when we use Omote's damage variables, we can discern no significant effect on product switching induced by the damage. Omote's damage variable suggests that while being located in more damaged areas reduces the probability of a firm switching its main product, greater capital intensity counteracts this effect. Table 5 reports marginal effects. The marginal increase in the interaction term of capital and damage raises the probability of product switch by 0.85%.

Table 5

4.3 Entry and extensive margin

After the earthquake, Yokohama City experienced a quick recovery in some traditional sectors such as textile dyeing and printing, more specifically known as "Yokohama Nassen (Yokohama scarves)". Simultaneously, new industries emerged, such as automobiles, bicycles, and industrial machinery. Furthermore, the boom of recovery after the earthquake stimulated demand for construction resources and materials such as metal parts and products, which allowed for a large number of new entrants in the metals sector.

To discuss the role of entry–exit in the industrial structural change after the earthquake, it is worthwhile to first make a comparison in capital among new entrants, exits, and survivors. Table 6 reports the number of firms and average capital of new entrants, survivors and exits at the sectoral level. The main sector was textiles before the earthquake. In textiles, many firms exited and were replaced by many new entrants. In contrast, the metals sector has a large number of new entrants despite only a small number of exits. Figure 8 shows histograms in terms of the capital of firms that enter and exit compared to survivors.[13] Compared with survivors, firms with smaller capital tended to exit and enter, while new entrants tended to be smaller than those that exit. This suggests that the earthquake crowded out small capital firms and accommodated small(er) new firms.

Table 6, Figure 8

Next, we investigate the relationship of capital with earthquake damage by estimating the following for the sample of surviving firms and new entrants in 1925:

$$\text{Capital1925}_{ir} = \beta_1 \text{DamageArea}_r + \beta_2 \text{Entry}_i + \beta_3 \text{Entry} * \text{Damage}_{ir} + \varepsilon_{ir} \qquad (4)$$

where *Capital1925* indicates the post-earthquake capital level in the year 1925 in firm *i*. *Damage* is the damage index at the chome-level, *r*. Entry is a dummy variable, which takes on the value of one if firm *i* is a new entrant after the earthquake and zero for survivors.

The first column of Table 7 reports the results. Accordingly, *Damage* and *Entry* are both significantly negative, while the interaction term of damage and entry, i.e., *Damage*Entry*, is significantly positive. Thus, in line with Figure 8, new entrants and firms in seriously damaged areas are likely to be smaller firms. However, new entrants

[13] Appendix Figure shows histograms in terms of the capital of entrants compared to those that exit.

located at seriously damaged areas tend to be larger capital firms than those in undamaged areas. We can interpret the result that if many damaged buildings and firms were quickly swept out in damaged areas, more space could be offered and thus attract larger new entrants. Capital intensive firms need larger space and thus tend to locate in formerly damaged areas.

Table 7

Similarly to the previous estimation, we conduct the same estimation using employment size.

$$\text{Employment1925}_{ir} = \beta_1 \text{DamageArea}_r + \beta_2 \text{Entry}_i + \beta_3 \text{Entry} * \text{Damage}_{ir} + \varepsilon_{ir} \quad (5)$$

where *Employment1925* denotes the number of employees in the year 1925. The results are shown in column 2 of Table 7 and are similar to the results related to the capital size of a firm. More specifically, the chome areas that sustained serious damage cleared many damaged buildings and therefore could accommodate large employment firms.

4.4 Capital growth comparison with an undamaged city (Osaka)—how large was the destructive creation?

Intrinsic to our analysis is that we use undamaged and less damaged firms as the control group in this 'natural experiment'. One problem with this assumption is of course that even firms in less or non-damaged areas may be indirectly affected by damages elsewhere in the city. Thus, arguably firms in other cities may make a more natural control group. Hence, we examine whether firms in Yokohama City grew capital at a higher speed than firms in undamaged cities with similar city characteristics. To this end, we compare Yokohama with Osaka City. As stated above, Yokohama City was one of the oldest and the biggest port cities in Japan. It exported raw silk and silk products to the U.S. and Europe, which were the largest export goods in Japan. Yokohama additionally had large textile sectors, such as silk products for exporting, silk dyeing and printing, and other textile products.

By contrast, Osaka City, the second-largest city and the center of commerce and manufacturing, had a large port and modern manufacturing technology. The population size of Osaka was 1.25 million as of 1920, which is larger than Yokohama City, which stood at 0.42 million. Osaka City exported cotton textiles and had large textile producing sectors. Most importantly, Osaka City was not damaged at all by the Great Kanto Earthquake. Thus, Osaka City could arguably serve as a good control group. To compare capital growth, we combine the firm-level data of Yokohama with comparable data from the firms located in Osaka City in the textile sector. To make a precise comparison, our samples are only from the textile sector, which was a major sector in both cities. The data for Osaka City is taken from the *Handbook of Manufacturing Firms in Osaka City* (*Osaka-shi Kojo Ichiran*), by the Bureau of Industry of Osaka City Office, (Osaka-shi Sangyou-bu).

Using firm data from Yokohama and Osaka, we estimate the following:

$$\text{Capital Growth}_{ir} = \beta_1 Cap_i + \beta_2 Cap * Osaka_{ir} + \beta_3 Damage_r + \beta_4 DamageCap_{ir} + \beta_5 Osaka + \varepsilon_{ir} \quad (6)$$

where the *Osaka* dummy takes one (zero) if firm i locates in Osaka (Yokohama) City. *Cap*Osaka* is the interaction of Osaka dummy and *Cap*.

Table 8 reports the results. As in our previous estimation, *Cap* is negative and *DamageCap* is positive. The Osaka dummy is significantly positive. Furthermore, *Cap*Osaka* is significantly positive. Thus, compared with Yokohama, the textile firms in Osaka City experienced higher capital growth. This implies that creative destruction in Yokohama was not substantially larger in the textile sector. There are two possible reasons for this. First, while Yokohama concentrated on silk products in the textile industry, Osaka was a center of the cotton weaving industry (Yokohama City ed. 1971, p.182; Abe 1989, pp.24–25), and cotton fabric production grew faster than silk fabric production in Japan in this period.[14] Second, the earthquake shifted the export center of silk products from Yokohama Port to Kobe Port, which in turn made silk fabric producers in Yokohama move to Kobe (Yokohama City Office ed. 1971, pp.223–224).[15]

Table 8

Importantly, this result can be seen only in the textile sector. The column 2 of Table 8 reports the results of the advanced technology sectors (chemicals, ships, and automobiles). In contrast to the textile sector, the advanced technology sectors portray an insignificant Osaka dummy and Cap*Osaka. This suggests that capital growth in Osaka was not significantly higher than in Yokohama. Thus, we can conclude that the

[14] Cotton fabric production in 1921 and 1925 was 534 and703 million yen, respectively, while silk fabric production in the same years was 309 and 273 million yen, respectively (Kajinishi ed. 1964, statistical appendix, p.43).

[15] This is a case of the persistent shift of industrial agglomerations caused by the Great Kanto Earthquake (Imaizumi, et al. 2016).

production shift from Yokohama to Osaka after the earthquake, which mitigated the creative destruction, happened mainly in the textile sector.

5. Prefectural estimations

As a further robustness check, we conduct prefectural level estimations using the *Manufacturing Census* (Ministry of Agriculture and Commerce of Japan). The Manufacturing Census is annually available only at the prefectural level, where Japan consists of 47 prefectures.[16] The census includes information on the number of firms (plants), the number of firms with machines (capital), the number of machines by type of engines, and horsepowers in each engine type, i.e. electric machine, vapor, turbine, water turbine, the Pelton wheel and Japanese traditional water wheel. It covers the period 1919 to 1926 except 1922.[17]

We take a difference-in-difference (DID) approach to isolate the effect of earthquake damages and estimate the following at the prefectural level:

$$\text{Growth\_num}_{pt} = \beta_1 Num_{\text{pt}} + \beta_2 PostQuake_t + \beta_3 Dam * PostQuake_{pt} + year + \omega_{\text{p}} + \varepsilon \quad (7)$$

where p indicates prefecture and t is year. ω_{p} is prefecture dummy. *Num* is [1] the number of firms, [2] the number of firms with machines (capital), and [3] the number of machines (capital) by each type of engine. *Growth_num* is the growth rate from t-1 to t in [1] to [3]. *Dam* is a damage variable measured by the percentage of fatalities caused

[16] We note that any micro level data in the Manufacturing Census in this period is not preserved anymore. Only aggregate data is available.
[17] Capital information is not available in the year 1922. From 1919, a Manufacturing Census is annually conducted.

by the earthquake in total population in each prefecture. The values are taken from the same source as Table 1. Seven prefectures are damaged, where Kanagawa Prefecture (Yokohama) is the highest (2.31%) and Tokyo Prefecture is the second highest (1.75%).[18] *PostQuake* is a dummy taking one in all years after 1923. *Damage*PostQuake* is the interaction of *Dam* and *PostQuake*.

First, the number of plants and plants with machines are investigated. The number of plants with machines is the so-called extensive margin. Columns 1 and 2 of Table 9 report the result of the growth in the number of firms. The interaction term of *Damage*PostQuake* is both significantly positive in the number of firms (Column 1) and the number of firms with machines (Column 2). More precisely, seriously damaged prefectures experienced a higher growth rate in the number of firms and the number of machine plants after the earthquake.

Table 9

We now turn to the impact on growth in machines by engine type. In this regard, it is notable that the Japanese economy was experiencing a motive power evolution in this period. Minami (1987), using Japan's Manufacturing Census data, studied how important the evolution of this type of motive power was in the Japanese industrialization from the late nineteenth century. More specifically, he illustrated the evolution of motive power, from traditional water wheels to the steam engine, and then from the steam engine to the electric motor. Within water power, traditional water

[18] An alternative damage variable is measured by the percentage of damaged buildings in total at prefectural level, as reported in Table 1. All estimation results are consistent with those by using the percentage of fatalities. We omit reporting results.

wheels were replaced by more advanced water turbines and Pelton wheels. Columns 3 to 7 of Table 9 report the results of using the growth of these more advanced machines as the dependent variable in (7). One finds that the *Damage*PostQuake* interaction term is significantly positive for machines with electric motors (Column 3) and with steam engines (Column 6).

Next, the growth in machine quality is explored (measured by average horsepower per machine). This is the so-called intensive margin.

$$\text{Growth\_Prod}_{pt} = \beta_1 Prod_{pt} + \beta_2 PostQuake_t + \beta_3 Dam * PostQuake_{pt} + year + \omega_p + \varepsilon \quad (8)$$

where p indicates prefecture and t is the year. ω_p are a vector of prefecture dummies. *Prod* is average horsepower per machine. Table 10 reports the results. Columns 1 and 4 are significantly positive in *Damage*PostQuake*. In Table 10, it is notable that the machines with electric motors increased more in seriously damaged prefectures. The coefficient on *Damage*PostQuake* for electric engines is 0.04 (Column 1), which is much larger than the coefficient for steam engines (Column 4). Minami (1987) revealed that electric motors diffused rapidly from the 1900s. The total horsepower of electric motors exceeded that of steam engines in the late 1910s, and the share of electric motors in the total motive power of manufacturing industries in Japan became higher than 80% in the late 1920s. In this sense, the 1920s is characterized by an “electric revolution”. The results in Table 10 suggest that the damage by the Great Kanto Earthquake accelerated the diffusion of electrical power.

Table 10

6. Conclusion

The Great Kanto Earthquake inflicted very serious damage on Yokohama City as well as Tokyo City. With respect to industries, about 90% of factories in Yokohama City were burnt down. However, manufacturing industries in Yokohama City recovered from the damage swiftly. As we showed, the number of factories and workers exceeded the 1921 levels in 1924 and 1927, respectively. Furthermore, we found some cases where firms exploited the damage by the earthquake to upgrade their factories. For example, Furukawa Electric Co. not only reformed the layout of its Yokohama Plant, but it also restructured the division of works between Yokohama plants and its other plants. Kirin Brewery Co. relocated the damaged Yokohama Yamate Plant to a new site and introduced advanced production equipment. These are typical cases of creative destruction that are generally just assumed in the literature on this topic.

We examined to what extent we can generalize these cases. Using plant-level data from Yokohama City, we found that in more damaged areas firm's capital measured by horsepower grew less, but that larger firms tended to increase their capital. Also, larger firms tended to switch products more in damaged areas. These results suggest that creative destruction indeed existed, but that the opportunity of creative destruction was open only to larger firms. In addition, we examined creative destruction using the prefecture-level data to see the difference in the growth paths between the damaged and undamaged prefectures. It was found that in the damaged prefectures, factories adopted electric motors more than in the undamaged prefectures.

These findings suggest that creative destruction indeed existed in the case of the Great Kanto Earthquake. Furthermore, it provides a new perspective on Japanese economic history in this period. In this literature, the period between the two World Wars was characterized by an upgrade of the industrial structure based on electric powers and the emergence of the "dual structure". Creative destruction by the Great Kanto Earthquake accelerated both of these two aspects in the evolution of the Japanese economy.

References

Abe, T. (1989). *Nihon niokeru Sanchi Menorimonogyo no Tenkai (Development of Cotton Weaving Clusters in Japan*), Tokyo: The University of Tokyo Press (in Japanese).

Arimoto, Y.,K. Nakajima and T. Okazaki (2014). "Sources of productivity improvement in industrial clusters: The case of the prewar Japanese silk-reeling industry," *Regional Science and Urban Economics*, vol. 46, pp. 27-41

Bank of Japan ed. (1983) *Nihon Ginko 100-nen Shi (100 Yeas-History of the Bank of Japan)*, vol.3, Tokyo: Bank of Japan (in Japanese)

Bernhofen, D. M., and Brown, J. C. (2005). "An empirical assessment of the comparative advantage gains from trade: Evidence from Japan". *The American Economic Review*, *95*(1), 208-225.

Cole, M. A., Elliott, R. J., T, Okubo, and Strobl, E. (2013). *Natural Disasters and Plant Survival: The impact of the Kobe earthquake,* RIETI Discussion Paper No. 13063.

Flath, D. (2005) *The Japanese Economy*, second edition, Oxford: Oxford University Press

Furukawa Electric Co. (1991). *Sogyo 100-nen Shi (100-Year History from the Foundation)*, Tokyo: Furukawa Electric Co. (in Japanese).

Hallegatte, S., and Ghil, M. (2008). "Natural disasters impacting a macroeconomic model with endogenous dynamics." *Ecological Economics*, *68*(1), 582-592.

Holding Companies Liquidation Committee (1950). *Nihon Zaibatsu to sono Kaitai (Japanese Zaibatsu and their Liquidation)*, volume of materials, Tokyo: Holding Companies Liquidation Committee

Imaizumi, A., K.Ito, and T.Okazaki (2016) "Impact of Natural Disasters on Industrial Agglomeration:The Case of the Great Kanto Earthquake in 1923," *Explorations in Economic History*, 60:52-68.

Kajinishi, M. (1964). *Sen'i (Textile Industry)*, vol.1, Tokyo: Kojunsha (in Japanese).

Kirin Brewery Co. (1957) *Kirin Biru Kabushiki Gaisha 50-nen Shi (50- Year History of Kirin Brewery Co.)*, Tokyo: Kirin Brewery Co.

Leiter, A. M., Oberhofer, H., and Raschky, P. A. (2009). Creative disasters? Flooding effects on capital, labour and productivity within European firms. *Environmental and Resource Economics*, *43*(3), 333-350.

Minami, R (1987) *Power Revolution in the Industrialization of Japan, 1885-1940* : Tokyo: Kinokuniya

Nakamura, T. (1983) *Economic Growth in Prewar Japan*, New Haven: Yale University Press

Noy, I., and duPont IV, W. (2016). "The long-term consequences of natural disasters-A summary of the literature," SEF Working paper 02/2016 (Victoria University of Welington)

Okazaki, T., (2016). "Senzen Nihon niokeru ginkogyo no sangyo soshiki to sangyo kigyo kin'yu" (Industrial organization of the banking industry and industrial and corporate finance in prewar Japan), CIRJE discussion paper series J-281 (The University of Tokyo) (in Japanese).

Okuyama, Y., (2004). "Modeling spatial economic impacts of an earthquake: Input–output approaches," *Disaster Prevention and Management*, 13 (4), 297–306.

Omote, S.(1949). "Earthquake damages in Yokohama City due to the Great Kwanto Earthquake of September 1,1923," *Bulletin of the Earthquake Research Institute*, Vol. 27, pp. 57-62.

Pereira, A. S. (2009). The opportunity of a disaster: the economic impact of the 1755 Lisbon earthquake. *The Journal of Economic History*, *69*(02), 466-499.

Schumpeter, J. (1942). *Capitalism, Socialism and Democracy*, 82-5, New York: Haper and Brothers

Shinomiya, M. (1998). *Nihon no Jidosha Sangyo: Kigyosha Katsudo to Kyosoryoku, 1918-70 (The Automobile Industry in Japan: Entrepreneurship and Competitiveness, 1918-70)*, Tokyo: Nihon Keizai Hyoronsha (in Japanese).

Takahama, T., S. Midorikawa, H. Shinbo and S. Abe (2001). "1923 nen Kanto Jishin niyoru Yokohama-shi deno Mokuzoukaoku no Higaibunpu" (Damage distribution of wooden houses in Yokohama City by the 1923 Kanto earthquake, in Proceedings of the 26th JSCE Earthquake Engineering Symposium, 1, 105-108 (in Japanese).

Teranishi, J. (2011). *Senzenki Nihon no Kin'yu Shisutemu (The Financial System in Prewar Japan)*, Iwanami Shoten (in Japanese).

Yamazawa, I and Y. Yamamoto (1979) *Boueki to Kokusaishushi* (*Trade and Balance of Payments*) Toyo Keizai Shinposha (in Japanese)

Yokohama City Office ed. (1926) *Yokohama Shi Shinsai Shi (Record of the Earthquake in Yokohama City)*, vol.3, Yokohama: Yokohama City Office (in Japanese).

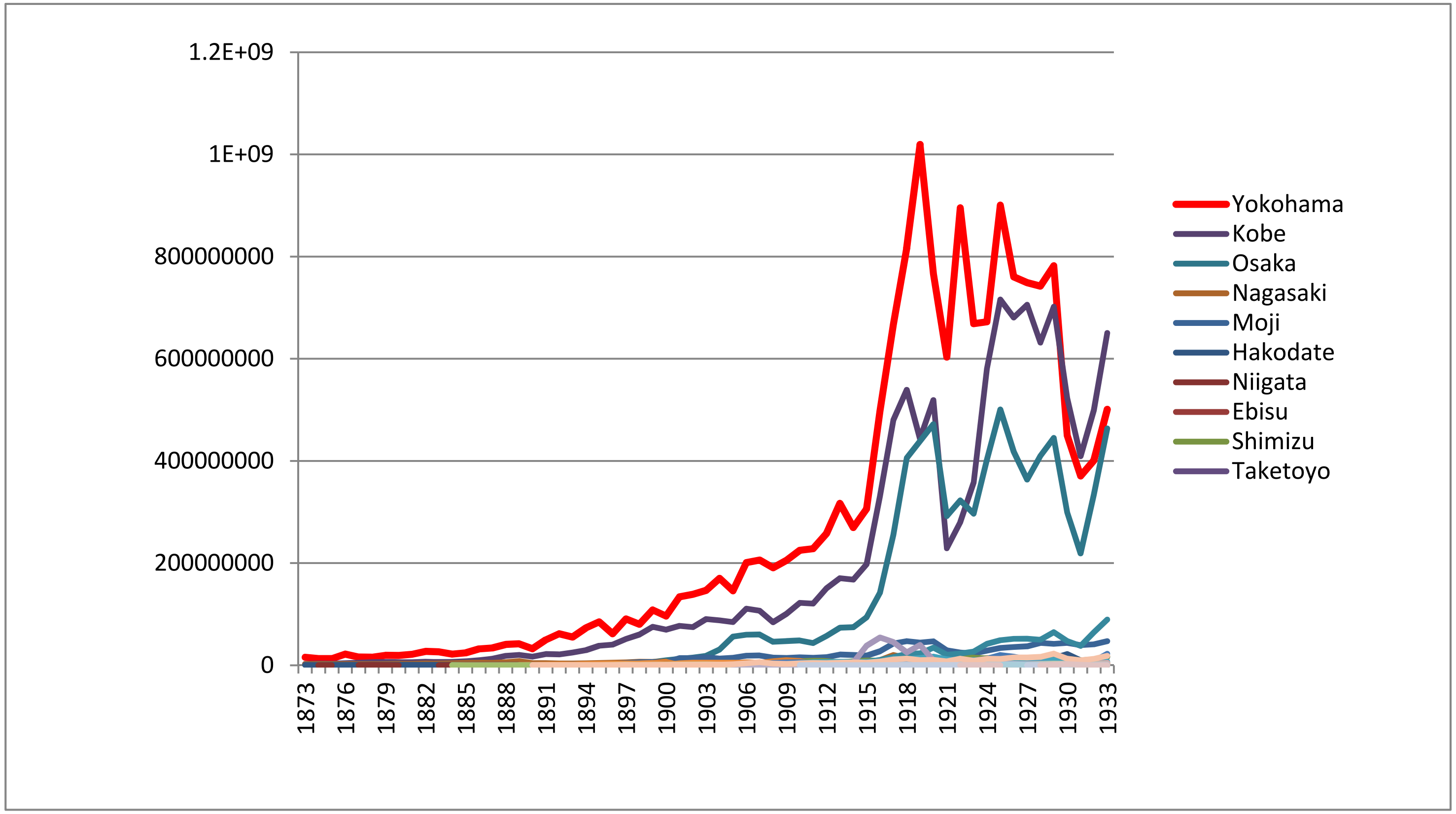
Yokohama City Office ed. (1971) *Yokohama Shi Shi (Hisotry of Yokohama City)*, vol. 5-1, Yokohama: Yokohama City (in Japanese).

Yokohama City Office ed. (1993) *Yokohama Shi Shi (Hisotry of Yokohama City)*, series 2, vol. 1-1, Yokohama: Yokohama City (in Japanese).

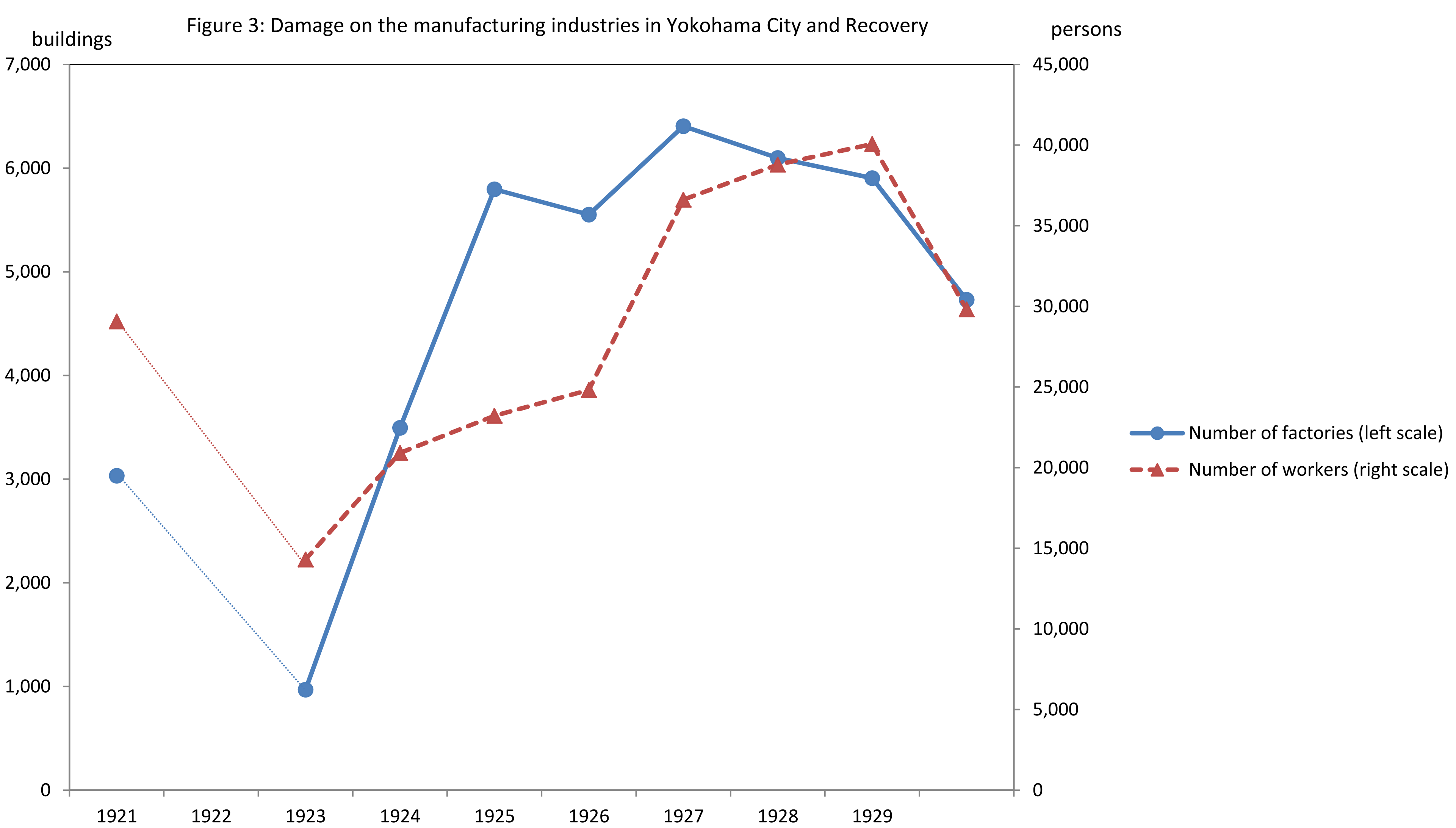
Yokota, R. (1944) *Jidosha 30 Nen Shi (30-Year History of Automobile)*, Tokyo: Sansuisha (in Japanese).

Figure 1: Map of Japan

Figure 2: Exports of international ports (unit: nominal yen)

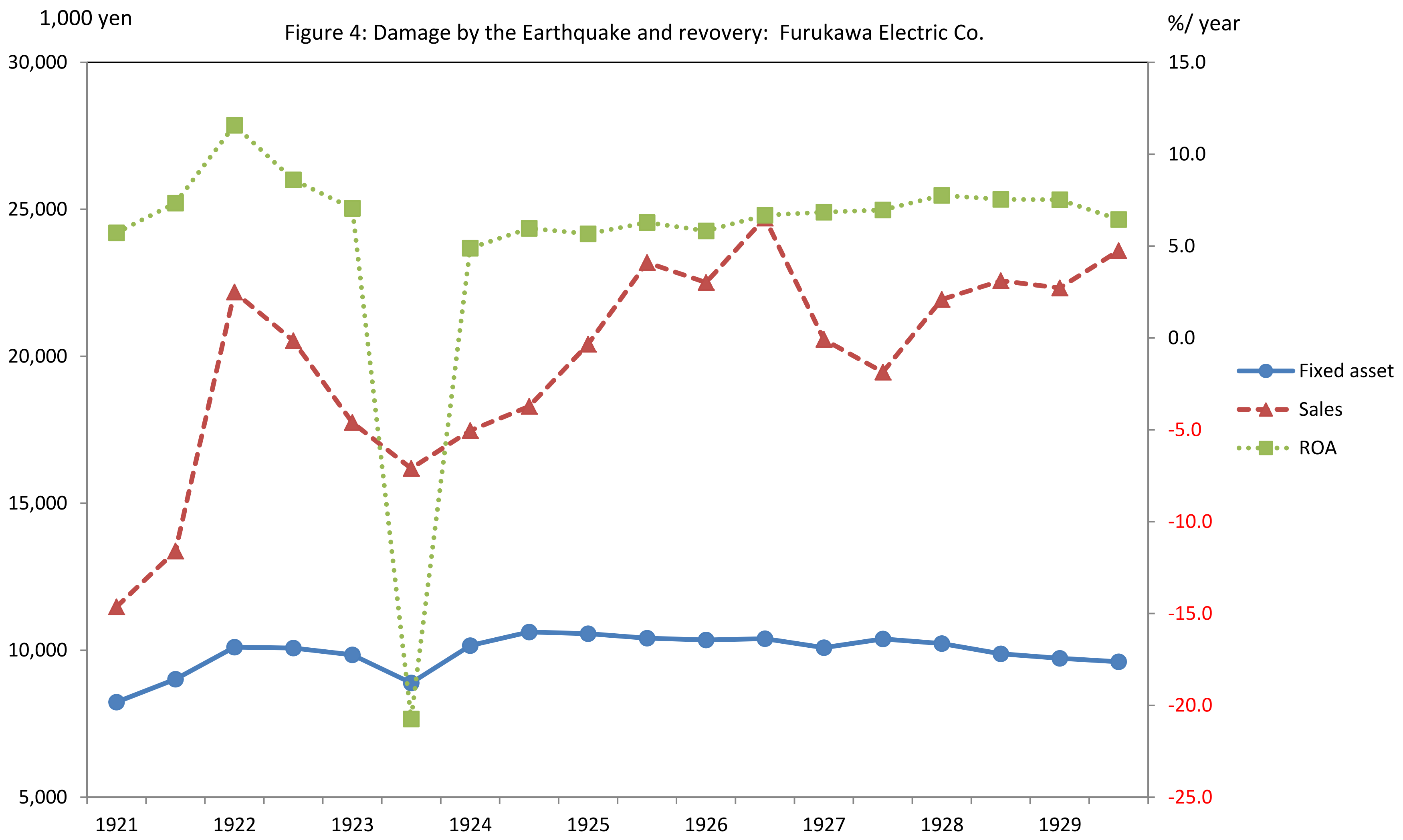


Source: Yamazawa and Yamamoto (1979)



Source: Yokohama City Office ed. (1976), p.170.

Figure 4: Damage by the Earthquake and revovery: Furukawa Electric Co.



Source: Furukawa Electric Co., *Business Report*, various issues.

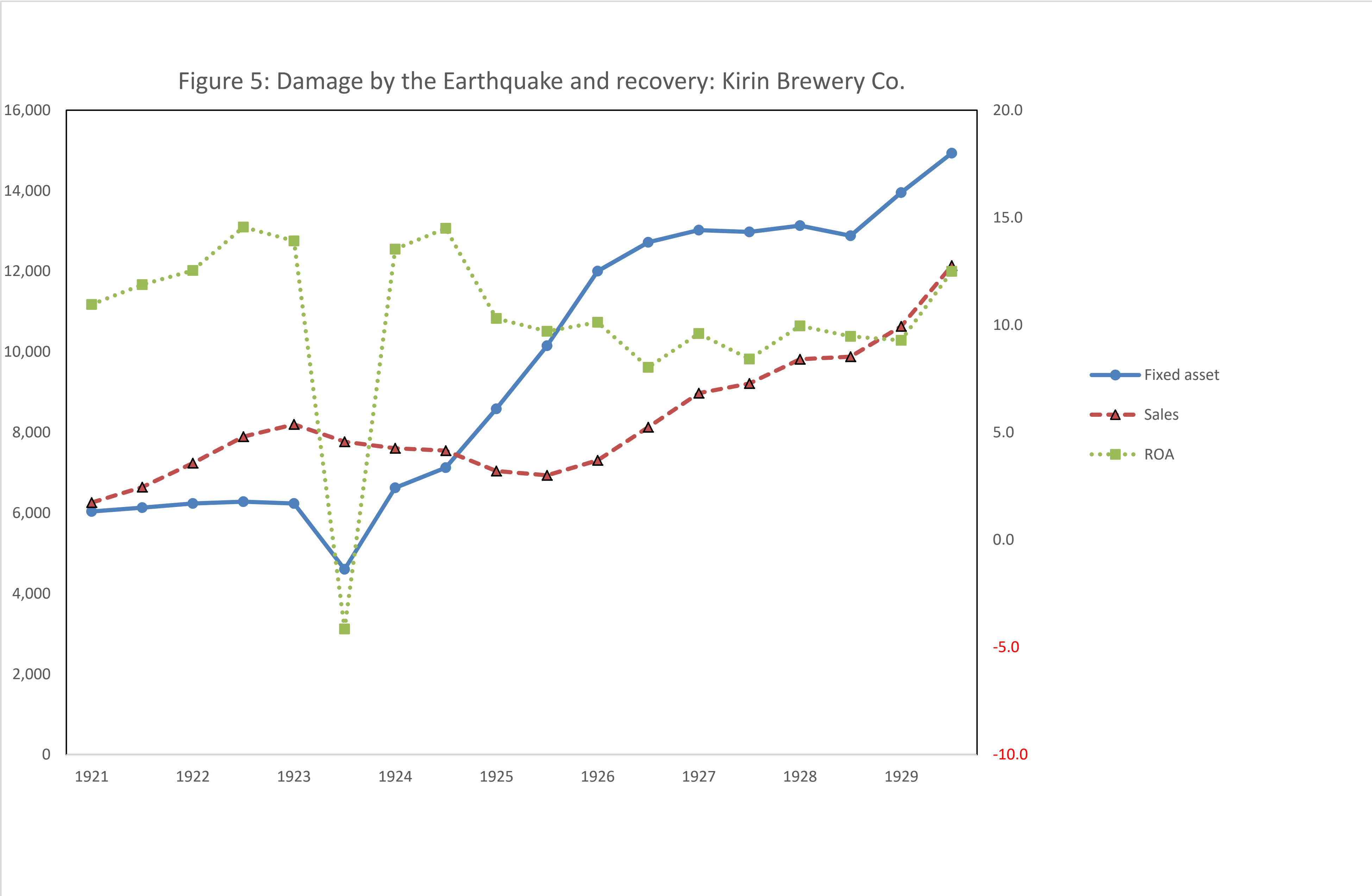
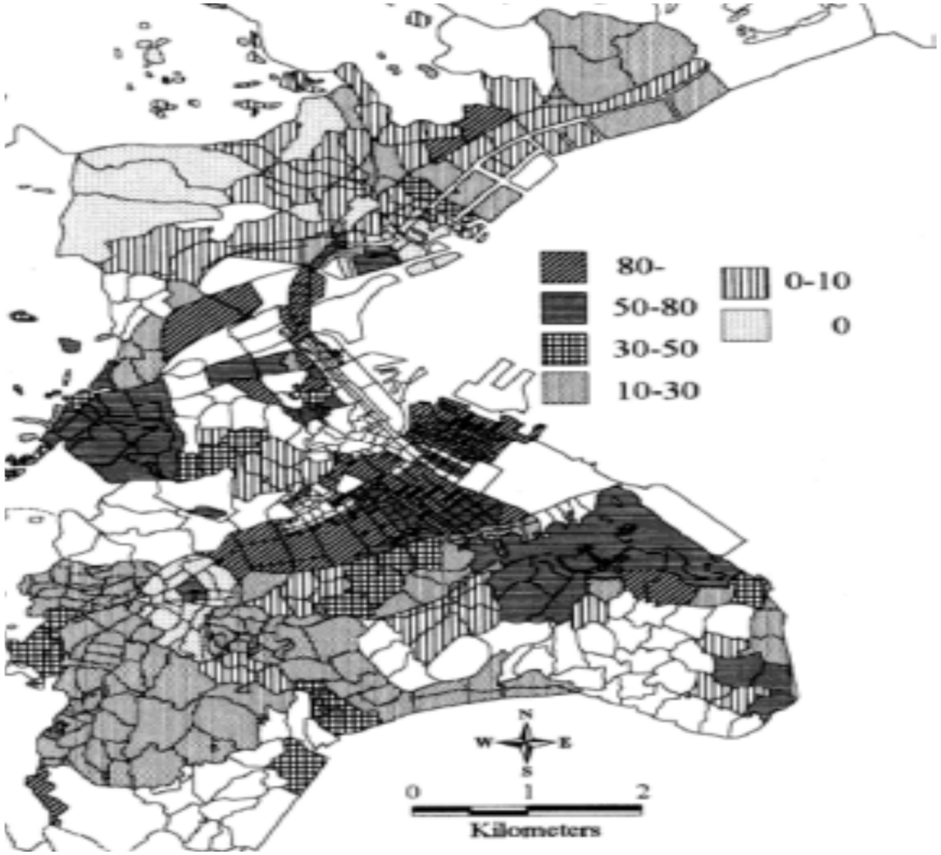


Figure 5: Damage by the Earthquake and recovery: Kirin Brewery Co.
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
1921
1922
1923
1924
1925
1926
1927
1928
1929
Fixed asset
Sales
ROA

Figure 6: Damage map in Yokohama city

Percentages of totally destroyed buildings at chome level.



Source: Takahama et al.(2001) Figure 3

Figure 7: Share of totally collapsed building (chome level)

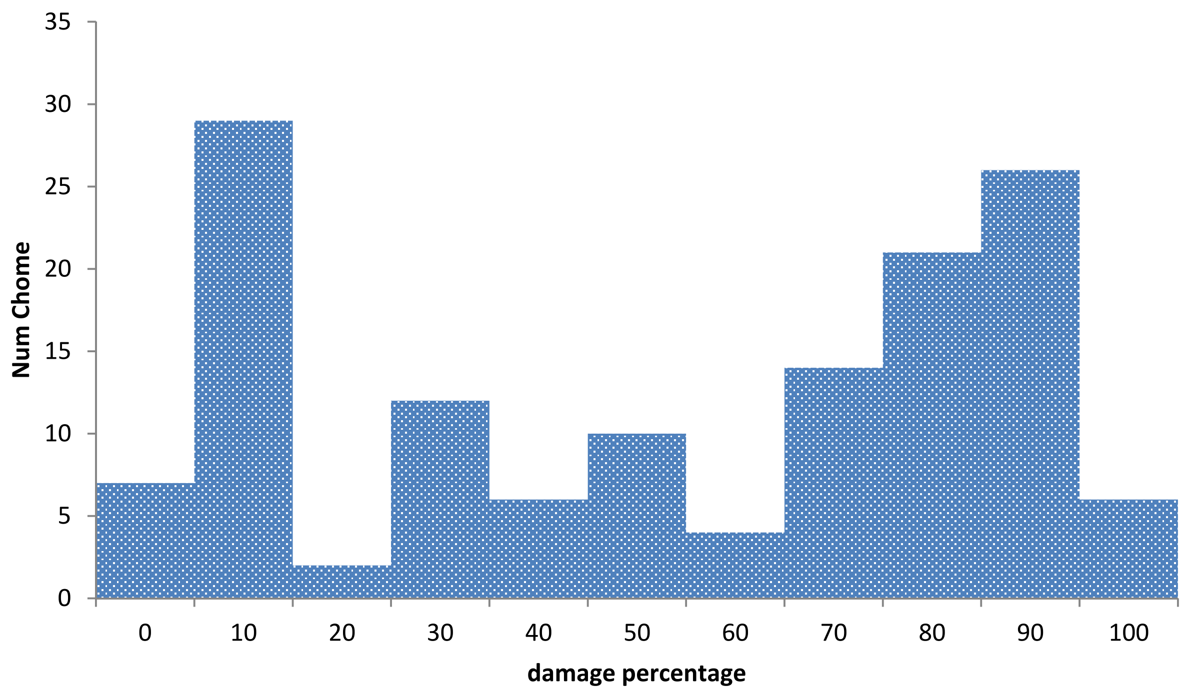
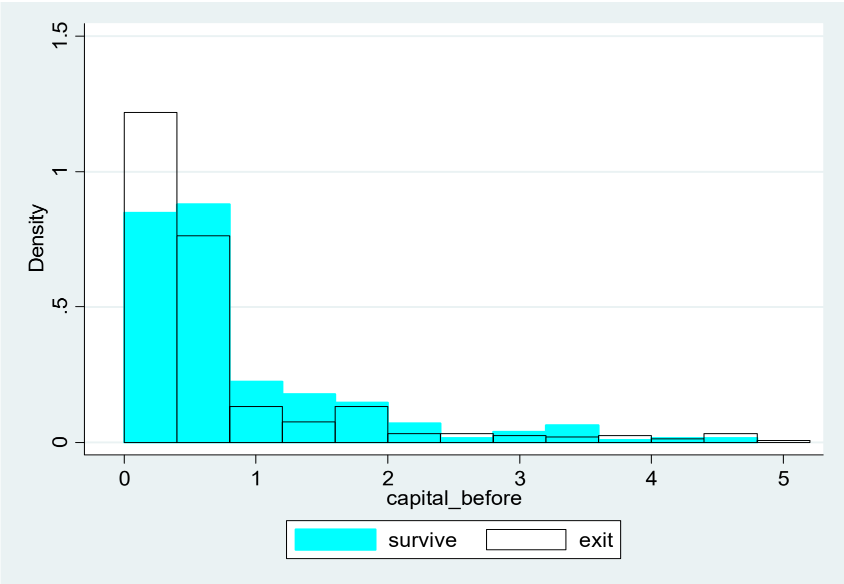
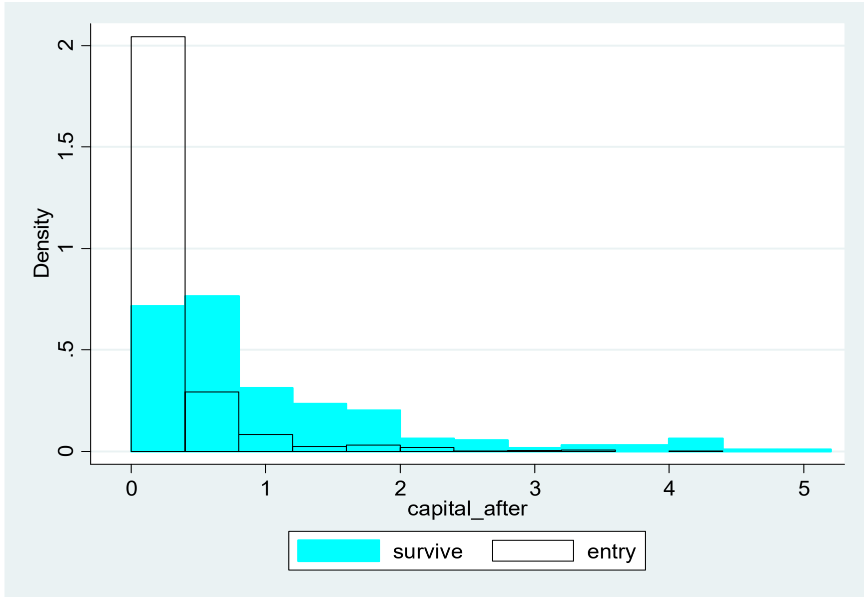


Figure 8: Capital size distribution



Surviver vs Exit (year 1921)



Surviver vs Entrant (year 1925)

Appendix Figure 1: Capital size distribution (exit and entrant)

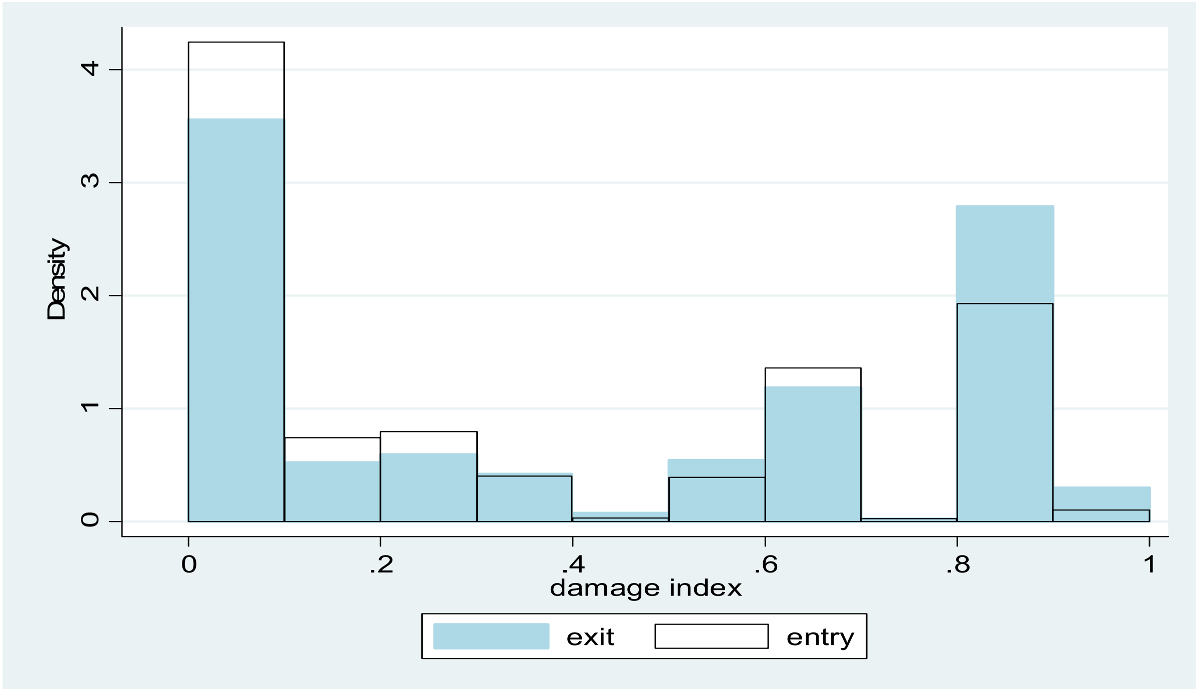


Table 1: Damage by the Great Kanto Earthquake

	Human damage			Physical damage		
Prefecture, city	Population just before the Earthquake	Number of death and missing		Number of buildings just before the Earthquake	Number of buildings completely destroyed or burnt	
	1,000 persons	1,000 persons	%	1,000 buildings	1,000 buildings	%
Total	11,743.1	104.6	0.89	2,284.2	464.9	20.4
Tokyo	4,035.7	70.5	1.75	826.6	328.6	39.8
Tokyo City	2,265.3	68.7	3.03	483.0	305.1	63.2
The other area	1,770.4	1.8	0.10	343.6	23.5	6.8
Kanagawa	1,379.0	31.9	2.31	274.3	115.4	42.1
Yokohama City	**446.6**	**23.3**	**5.23**	**98.9**	**72.4**	**73.2**
The other area	932.4	8.5	0.91	175.4	42.9	24.5
Chiba	1,347.2	1.4	0.11	262.6	13.4	5.1
Saitama	1,353.8	0.3	0.02	244.9	4.6	1.9
Shizuoka	1,626.3	0.5	0.03	289.1	2.3	0.8
Yamanashi	602.0	0.0	0.00	117.0	0.6	0.5
Ibaraki	1,399.1	0.0	0.00	269.7	0.2	0.1

Source: Tokyo City Government (1925), pp.160–163.

Table 2: Damage on factories in Yokohama City

	Number of factories before the Earthquake	Nimber of factories burnt	Percentage	Workers of the burnt factories
Total	2,886	2,547	88.3	29,105
Textile	485	430	88.7	4,160
Machinery	319	249	78.1	8,335
Chemical	194	150	77.3	4,405
Foods	1,178	1,041	88.4	5,060
Miscellaneous	700	670	95.7	5,745
Utilities	10	7	70.0	1,670

Yokohama City ed. (1926) vol.3, pp.393–399.

Table 3: Capital growth

Dependent variable: Capital growth(1921-1925)

	1		2		3	
Cap (year 1921)	−0.39361	−6.9 ***	−0.40458	−7.1 ***	−0.39656	−6.78 ***
Damage1(chome)	−0.45147	−2.07 **	−0.50392	−2.27 **	−0.50168	−2.22 **
Damage1 X Cap	0.364848	2.34 **	0.405224	2.59 **	0.442131	2.74 ***
Foreign owner			0.15101	0.28	0.133295	0.24
Reloctaion			0.076059	0.55	0.081951	0.59
Age			−0.01093	−0.16	0.016535	0.24
Export only before			2.912087	3.77 ***	3.065664	3.95 ***
Num building (chome)					0.076941	1.56
Artificial area(chome)					−0.12421	−0.68
Cons	0.624505	6.35 ***	0.630357	3.47 ***	0.081735	0.21
Nob	333		327		317	
R-sq	0.17		0.202		0.201	
	product fixed effect		product fixed effect		product fixed effect	

"Damage 1" is the share of totally collapsed building, (0 to 1). Data source is Takahama et al.(2001)

Capital measured by horsepower of machines

Export_only_before is dummy for export product firm (before quake)

Num_bulding is the number of bulidings at Chome level before earthquake

Artificial area is dummy for artificially made area (artificial island and port)

***, **, and * show 1%, 5%, and 10% significance, respectively.

Table 4: Survival estimation

Dependent variable: Survival dummy (0=exit or 1=survive)

Marginal effect

	1			2		
Cap	0.002037	0.04		-0.08122	-1.16	
Damage1(chome)	-0.6745	-3.7	***			
Damage(omote)				-1.22814	-5.66	***
Damage1 X Cap	0.409339	2.6	***			
Damage (omote) X Cap				0.38805	2.75	***
Foreign owner	-0.65347	-1.55		-0.56813	-1.24	
Age	0.126187	2.12	**	0.187876	2.94	***
Export only before	0.184746	0.32		0.063299	0.11	
Num building (chome)	-0.07337	-1.65	*	-0.04355	-0.95	
Artificial area(chome)	-0.25187	-1.68	*	0.030259	0.18	
Nob	688			630		
Loglikelihood	-432.668			-388.289		
LR Chi	26.25			42.46		
	probit			probit		
	product dummy			product dummy		

Export only is dummy for export product firm (before quake)

Num_bulding is the number of bulidings at Chome level before earthquake

Artificial area is dummy for artificially made area (artificial island and port)

Capital measured by horsepower of machines

"Damage 1" is taken from Takahama et al (2001)

"Damage (Omote)" is taken from Omote (1949)

***, **, and * show 1%, 5%, and 10% significance, respectively.

Table 5: Product Switch

Dependent variable: product switch dummy (0=non-switch or 1=switch)

Marginal effect

	1			2		
Cap	−0.2304	−1.51		−0.56619	−1.83	*
Damage1(chome)	−0.13881	−0.28				
Damage(omote)				−0.34854	−0.55	
Damage1 X Cap	0.249883	0.78				
Ddamage (omote) X Cap				0.851268	1.72	*
Age	−0.15265	−1.17		−0.17857	−1.31	
Foreign owner	−5.50724	0		−5.32032	0	
Export only before	−5.1911	0		−4.60882	0	
Num building (chome)	0.000197	1.59		0.00017	1.37	
Artificial area(chome)	−0.01258	−0.04		−0.35618	−1.03	
Nob	191			191		
Loglikelihood	−94.1463			−91.1549		
LR Chi	6.97			8.86		
	probit			probit		
	chome dummy			chome dummy		

Export only is dummy for export product firm (before quake)

Num_bulding is the number of bulidings at Chome level before earthquake

Artificial area is dummy for artificially made area (artificial island and port)

Capital measured by horsepower of machines

"Damage 1" is taken from Takahama et al (2001)

"Damage (Omote)" is taken from Omote (1949)

***, **, and * show 1%, 5%, and 10% significance, respectively.

Table 6: Exit, survival and entry by sector

Exit

sector	average capital (1921)	Num firms
Textile	0.453958	238
Machinery	0.789674	40
Metal	1.247638	48
Chemical	0.842561	65
Other Manufacturing	1.063393	14
Total	0.664616	405

Survival

sector	average capital (1921)	Num firms
Textile	0.752745	107
Machinery	1.06055	108
Metal	0.954644	50
Chemical	1.035304	51
Other Manufacturing	0.945497	17
Total	0.936004	333

Entry (after Earthquake)

sector	average capital (1925)	Num firms
Textile	0.30039	302
Machinery	0.2297	356
Metal	0.088797	589
Chemical	0.264837	116
Other Manufacturing	0.131953	20
Total	0.186661	1383

NB: "average capital" is mean of log (horsepower)

Table 7: Entry after the Earthquake (1925)

	1		2	
	Capital in year 1925		Emp year in 1925	
Damage	−0.41904	−3.28 ***	−0.42989	−3.97 ***
Entry	−0.99437	−14.68 ***	−0.92098	−16.03 ***
Damage*Entry	0.304419	2.15 **	0.336712	2.8 ***
Const	1.236594	20.46 ***	1.982553	38.72 ***
Nob	1634		1622	
Sample	Surviver + New entrant		Surviver + New entrant	

***, **, and * show 1%, 5%, and 10% significance, respectively.

Table 8: Comparison of Osaka and Yokohama cities

Sample: Firms in Osaka and Yokohama cities

	(1) Textile sector			(2) Mordern sectors		
	Capital growth			Capital growth		
Cap	−0.5392	−2.64	***	−0.46406	−1.38	
CapDamage	0.4692	1.48		0.395673	0.59	
Damage	−0.0564	−0.16		−0.90383	−1.73	*
Osaka	0.3802	1.7	*	0.300566	0.84	
Cap*Osaka	0.442	2.14	**	0.308824	0.91	
Const	0.5208	2.52	**	0.765373	2.44	**
R−sq	0.11			0.18		
Nob	287			149		
OLS				OLS		

***, **, and * show 1%, 5%, and 10% significance, respectively.

Note: Mordern sectors are chemical products, chemical fertilizer, soap, medicine, automobile, bicycle, ship, automobile parts and components, repairment of car and ship

Table 9: Prefectural level DID analysis (extensive margin)

	1		2	
Dependent variables	D.Num Plant		D.Num Plants with Machines	
Damage*Post quake	0.187	4.83 ***	0.045	4.56 ***
Num plant	1.0265	18.74 ***		
Num machine plants			1.078	31.21 ***
Post quake	0.5805	7.33 ***	−0.2	−4.56 ***
Dummy	Year, pref		Year, pref	
Nob	282		282	
N of groups	47		47	
R−sq	0.7875		0.815	

	3		4		5		6		7	
Dependent variables	D.Num Electric motors		D.NumTurbine		D.NumWaterTurbine		D.Num Steam engines		D.Num Peltonwheel	
Damage*Post quake	0.1402	6.52 ***	0.109	0.91	0.02	0.57	0.15956	10.42 ***	0.0605	0.71
Num Electric motor	0.8154	8.79 ***								
Num Turbine			0.825	6.72 ***						
Num Water Turbine					0.716	6.86 ***				
Num Steam engine							0.69513	6.95 ***		
Num Pelton wheel									0.7783	4.78 ***
Post quake	0.1002	1.89 *	−0.2	−2.15 **	−0.37	−2.52 **	0.04471	1.56	−0.263	−1.85 *
Dummy	Year, pref		Year, pref		Year, pref		Year, pref		Year, pref	
Nob	282		282		282		282		282	
N of groups	47		47		47		47		47	
R−sq	0.6438		0.333		0.371		0.4247		0.406	

Robust standard error, cluster by 47 prefectures
Growth = level + pref dummies + post quake + post quake damage
Year: 1919, 1920, 1921, 1923, 1924, 1925, 1926
post_quake is year dummy after the earthquake (1924, 1925, 1926)
Damage variable is the number of casualties at prefectural level.
***, **, and * show 1%, 5%, and 10% significance, respectively.

Table 10: Prefectural level DID analysis(intensive margin): Engine quality

	1		2		3		4		5	
Dependent variables	D. Electric motors		D.Turbine		D.WaterTurbine		D. Steam engines		D. Peltonwheel	
Damage*Post quake	0.0468196	4.76 ***	0.03386	0.24	0.1146012	0.51	0.0236956	3.16 ***	0.0604129	0.27
Elec motors	1.05396	9.72 ***								
Steam engine							0.8243171	11.19 ***		
Turbine			0.7682344	8.95 ***						
Water Turbine					0.718724	7.59 ***				
Pelton wheel									0.6270681	4.01 ***
Post quake	−0.135509	−5.47 ***	−0.228758	−1	−0.469922	−1.5	0.0293975	1.64 *	−0.377741	−1.07
Dummy	Year, pref		Year, pref		Year, pref		Year, pref		Year, pref	
Nob	282		266		242		282		192	
N of groups	47		42		42		47		38	
R−sq	0.5993		0.439		0.3417		0.3904		0.2851	

Robust standard error, cluster by 47 prefectures
Growth = level + pref dummies + post quake + post quake damage
Year: 1919, 1920, 1921, 1923, 1924, 1925, 1926
Damage variable is the number of casualties at prefectural level.
post_quake is year dummy after the earthquake (1924, 1925, 1926)
***, **, and * show 1%, 5%, and 10% significance, respectively.

Appendix Table 1: Basic Statistic

1 Firm level estimations

stats	Capital growth	Cap (year 1921)	Foreign owner dum	Age	Export only before	Damage 1	Damage1 X Cap	Damage Omote	Damage Omote X cap	Num building (chome)	Road damage(chome)	Artificial area(chome)
mean	0.2103211	0.9360042	0.012012	2.233657	0.006006	0.3168468	0.2666539	0.4698769	0.4013297	6.22958	0.033033	0.1321321
min	−7.133296	0	0	0.6931472	0	0	0	0	0	0	0	0
max	5.081404	8.930627	1	3.988984	1	0.93	4.754883	0.95	3.698242	8.216088	1	1
sd	1.189496	1.28053	0.109103	0.8913183	0.0773816	0.3510329	0.5474184	0.3567347	0.6313534	1.289583	0.1789918	0.339144

2 Prefectural level estimation

stats	Damage*Post quake	Num plant	Num machine plants	Num Electric engines	Num steam engine	Num Turbine	Num Water Turbine	Num Pelton wheel	Electric engine	Steam engine	Turbine	Water Turbine	Pelton wheel
mean	0.0385167	6.534862	6.157943	6.56305	4.739356	2.184887	2.367411	1.262553	0.9054121	1.1768	4.060635	4.898365	3.904764
min	0	3.433987	3.044523	9.857758	6.565265	5.225747	4.584968	3.258096	1.446252	1.663569	8.40387	8.497352	9.328123
max	2.31	9.10019	8.999866	2.397895	3.401197	0	0.6931472	0	−0.3528201	0.0056641	0	−0.4054651	−0.6931472
sd	0.2746836	0.9668694	1.06679	1.299453	0.8042364	1.026377	0.9134093	0.9644773	0.2736603	0.2630944	2.486528	2.294176	2.351987

3 Number of firms in firm level estimations (post-earthquake)

	Num firms
Exit	404
Entrant	1389
Survived firms	334
Product swith	59
Relocation	86

Appendix Table 2: Employment growth
Dependent variable: employment growth

	Emp_growth		
Emp	−0.48392	−3.55	***
Damage	−0.56021	−0.35	
EmpXDamage	0.165466	0.35	
Const	1.004646	1.86	*
Nobs	70		
	sector dummies		

"Emp" is employee before the earthquake