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# The Impacts of Natural Disasters on Plants' Growth: Evidence from the Great Hanshin-Awaji (Kobe) Earthquake

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# The Impacts of Natural Disasters on Plants' Growth: Evidence from the Great Hanshin-Awaji (Kobe) Earthquake

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Abstract

The Great Hanshin-Awaji (Kobe) Earthquake in 1995 affected numerous plants in Kobe. In this study, I focus on this earthquake and use plant-level data to re-examine the creative disaster hypothesis which states that natural disasters enhance the growth of firms or plants in the affected areas. I employ the matching method and the difference-in-difference (DID) approach to reveal the effects of the quake. The results show that the plants that survived in the most devastated districts of Kobe faced severe negative effects in terms of employment growth and value added in the subsequent three years. This result is not consistent with previous empirical studies that support the creative disaster hypothesis.

*Keywords*: Natural disasters, Difference-in-difference, Plant growth

*JEL classification*: Q54, R11, C21



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# 1 Introduction

The Great Hanshin-Awaji (Kobe) earthquake occurred on January 17, 1995. It was one of the largest natural disasters in Japanese history. The death toll reached 6,437[*1] and the number of injured was 43,792 (Hayashi, 2011). Further, 182,751 buildings were completely destroyed. It severely affected the economy of the Japanese port city of Kobe and its surrounding area. The estimated economic damage was 9,926.8 billion yen, which is approximately 2.1% of Japan's GDP.

The aim of this study is to investigate the impacts of the quake on the growth of affected plants in Kobe. Previous studies on natural disasters such as Leite et al. (2009) confirm the creative disaster hypothesis that natural disasters enhance the growth of firms or plants in the affected areas. The Kobe quake is an ideal case for testing this hypothesis because it was unexpected and affected a large industrial area. After the quake, many studies have examined the economic impacts of the quake. However, none of these studies employ plant-level data or examine the creative disaster hypothesis.

In this study, I employ plant-level data and both difference-in-difference (DID) and matching techniques. The empirical results of this study are not consistent with the creative disaster hypothesis. The plants that survived in Kobe experienced lower employment growth and value added in the three years following the quake than plants in unaffected areas, although some of them experienced a higher growth of capital. This finding suggests that we need to reconsider the creative disaster hypothesis in the case of severe natural disasters.

The remainder of this paper is organized in the following manner. In Section 2, I review the literature and explain the creative destruction hypothesis. In Section 3, I provide a description of the data used in this study and provide an overview of the economic impacts of the quake on plants in Kobe. In Section 4, I explain the methodology, and in Section 5, I present the results. Finally, in Section 6, I present the conclusion.

# 2 The creative destruction hypothesis

Natural disasters usually tend to have negative impacts on the economy. Indeed, natural disasters have destroyed physical and human capital as well

[*1] The death toll of the great Kanto quake and that of the great east Japan quake were 105,000 and 15,845, respectively.

as public infrastructure. In the case of the Kobe quake, many studies have found substantial economic loss (Hayashi, 2011; Hondai and Uchida, 1998). However, several empirical studies report a positive correlation between the frequency of natural disasters and long-run economic growth. Skidmore and Toya (2002) investigate the long-run impact of natural disasters on growth for the period 1960–1990. They find that the frequency of climatic disasters is positively correlated with human capital accumulation, total factor productivity (TFP) growth, and GDP per capita growth.

The positive economic effect of natural disasters is termed creative destruction (Cuaresma et al., 2008) or creative disasters (Leiter et al., 2009). This is because the positive correlation can be interpreted as evidence that natural disasters provide opportunities to update existing capital stock and adopt new technologies, thereby functioning as a type of Schumpeterian creative destruction. Previous empirical studies such as Skidmore and Toya (2002) and Leiter et al. (2009) are consistent with the creative destruction hypothesis.[*2]

The contribution of this study to existing literature is twofold. First, this study employs plant-level data. Skidmore and Toya (2002) employ cross-country macroeconomic data and Leiter et al. (2009) employ European firm-level data. Both types of data cannot capture the pure effects of natural disasters since such data include unaffected plants or regions. Even if we observe positive effects of natural disasters at the country or firm level, the direct effects on plants in the affected area can be negative. From the viewpoint of the affected area's local government policymakers, the effect on plants in their area is the most important. To the best of my knowledge, thus far, no study has used plant-level data to investigate the effects of natural disasters.

Second, this study employs the matching technique to control for prequake plant characteristics. After matching plants in the affected area with those in the unaffected area, this study compares their growth path. This will yield more precise impacts of the natural disaster. Previous studies on the Kobe quake and other natural disasters employ neither plant-level data nor the matching technique. Therefore, this study is the first empirical study that provides the precise impacts of a natural disaster at the plant-level.

[*2] Siodla (2012) also studies the positive impacts of a disaster but it focuses on urban redevelopment.

# 3 Empirical strategy

This study employs two empirical methods to examine the impact of the Kobe quake on plant growth. First, following Leiter et al. (2009), this study employs a simple DID estimation. Second, this study employs the matching method with the DID approach.

I distinguish affected plants from nonaffected plants on the basis of their location. I regard plants in Kobe as affected plants and those in other areas as nonaffected plants. Plants in Osaka and other designated areas around Kobe that obtained special support from the government after the Kobe quake as part of the Disaster Relief Act are excluded from the analysis.

## 3.1 Difference-in-difference (DID) estimation

Using DID estimation, I compare plants in the most devastated area of Kobe with those in other major cities designated by government ordinance (*seirei shitei toshi* in Japanese): Kyoto, Nagoya, Yokohama, Kitakyusyu, Sapporo, Kawasaki, Fukuoka, Hiroshima, Sendai, and Chiba. Following Leiter et al. (2009), I estimate the following DID equation.

$$\begin{aligned} \ln y_{isr,t} = \eta_0 + \beta_1 * \ln y_{isr,1993} + \beta_2 * kobe_r + \beta_3 * after_t \\ + \beta_4 * (kobe * after)_{r,t} + industry_s + \epsilon_{isr,t}, \end{aligned} \quad (1)$$

where $i$, $s$, $r$, and $t$ index plant, industry, region, and year, respectively. The year $t$ represents the period from 1995 to 1998. The dependent variables, $\ln y_{isr,t}$, are log of employment (number of workers) and log of capital. I included their initial value in 1993, $\ln y_{isr,1993}$, as one of the explanatory variables, following Leiter et al. (2009) and firm growth literature. Further, $kobe_r$ is a treatment dummy variable that takes the value of one if a plant is located in Kobe, while $after_t$ is a dummy variable that takes the value of one after the year 1995—when the Kobe quake occurred. Therefore, $(kobe * after)_{r,t}$ is the DID dummy that captures the effects of the Kobe quake. Finally, $industry_s$ is an industry fixed effect and $\epsilon_{isr,t}$ is an error term.

Based on the Cobb-Douglas production function, I regress the log of value added in the following manner:

$$\begin{aligned} \ln v_{isr,t} = \delta_0 + \delta_1 * \ln k_{isr,1993} + \delta_2 * \ln l_{isr,1993} + \delta_3 * kobe_r + \delta_4 * after_t \\ + \delta_5 * (kobe * after)_{r,t} + industry_s + \eta_{isr,t}, \end{aligned} \quad (2)$$

where $\ln v_{isr,t}$ is the log of value added, while $\ln k_{isr,1993}$ and $\ln l_{isr,1993}$ are the initial values of log of capital and log of employment, respectively. $\eta_{isr,t}$

is an error term. As indicated by Leiter et al. (2009), the coefficient of DID dummy, $\delta_5$, captures productivity effects of the disaster.

## 3.2 Matching method

I employed mathing methods to compare affected plants with unaffected plants and evaluate the effects of the quake on the growth of employment, capital, and value added.

The effects of the Kobe quake on plant $i$'s outcome variables, $\Delta z$, can be written as

$$\Delta z^1_{i,t+g} - \Delta z^0_{i,t+g}, \tag{3}$$

where $z$ represents log of employment, capital, and value added. Superscript 0 refers to the nontreatment case (nonaffected case), and 1 refers to the treatment case (affected case). $t$ represents the year in which the quake occurred. The fundamental problem of the causal inference is that $\Delta z^0_{i,t+g}$ is unobservable. I adopted mathing methods to construct an appropriate counterfactual that can be used instead of $\Delta z^0_{i,t+g}$.

Using such methods, I examined the average effect of treatment on the treated (ATT) in the following manner

$$\begin{aligned} \delta &= E(\Delta z^1_{i,t+g} - \Delta z^0_{i,t+g} | D_{it} = 1) \\ &= E(\Delta z^1_{i,t+g} | D_{it} = 1) - E(\Delta z^0_{i,t+g} | D_{it} = 1), \end{aligned} \tag{4}$$

where $D_{it}$ indicates whether a plant $i$ is affected by the quake in year $t$. Using mathing methods, I construct the counterfactual for the last term, $E(\Delta z^0_{i,t+g} | D_{it} = 1)$.

Firms are matched with one-to-one and one-to-three nearest-neighbor matching methods. In the case of the one-to-one nearest-neighbor matching method with replacement, a plant that has the closest value of employment or capital or value added before the quake is selected for each affected plant $i$ in the following manner:

$$c(i) = \min_{j \in \{D_{jt}=0\}} ||z_{i,\hat{1}993} - z_{j,\hat{1}993}||. \tag{5}$$

Firms are matched separately for each two-digit industry. After constructing the control group by this matching method, the ATT is estimated.

Table 1: Aggregated variables of manufacturing plants in Kobe city (1993–2000)

| Year | No. of plants | | No. of workers | | Capital | | Value added | |
|---|---|---|---|---|---|---|---|---|
| | Level | Recovery rate (%) | Level | Recovery rate (%) | Level (billion) | Recovery rate (%) | Level (billion) | Recovery rate (%) |
| 1993 | 4,197 | (100.0) | 105,227 | (100.0) | 1,010.6 | (100.0) | 1,466.8 | (100.0) |
| 1994 | 525 | (12.5) | 41,874 | (39.8) | 646.2 | (63.9) | 919.7 | (62.7) |
| 1995 | 3,308 | (78.8) | 88,207 | (83.8) | 885.5 | (87.6) | 1,299.6 | (88.6) |
| 1996 | 3,215 | (76.6) | 83,274 | (79.1) | 869.1 | (86.0) | 1,267.6 | (86.4) |
| 1997 | 3,111 | (74.1) | 81,862 | (77.8) | 931.4 | (92.2) | 1,288.2 | (87.8) |
| 1998 | 3,137 | (74.7) | 80,456 | (76.5) | 980.2 | (97.0) | 1,352.2 | (92.2) |

Notes: The data is taken from the annual report of the Census of Manufactures. The data on capital is the sum of tangible fixed assets of plants with more than 10 employees. The recovery rate indicates the ratio of each year's values to the values in 1993.

# 4 Data and overview

In this section, I describe the data used in my empirical analysis. The data is taken from the Census of Manufactures, which is an annual compulsory survey conducted by the Ministry of Economy, Trade, and Industry (METI). The survey covers all manufacturing plants in Japan that have more than four employees[*3]. The response rate is rather high, over 90%. The range of variables collected by the survey depends on year and plant size. For example, data on capital are collected for plants with more than 10 employees. In the empirical analysis, all nominal values are deflated by an industry-level deflator, which is taken from the System of National Account Statistics.

Table 1 reports the number of plants, number of workers, sum of capital (fixed tangible asset), and sum of value added in Kobe before and after the quake. Table 1 also reports the recovery rate, ratio of each year's values to 1993 values. The results of the year 1994 are unreliable because the number of plants is rather small. Most plants in Kobe could not respond to the survey because the Kobe quake occurred on January 17, 1995—a little while after the 1994 survey was initiated on December 31, 1994. Therefore, I do not use the 1994 survey in my analysis.

[*3]The survey covers plants with less than three employees for some years before 2008, but this study analyzes plants with more than four employees because of computational limitations.

Table 2: Number of plants and fraction of plants by plant type

| | Exit plants | New plants | Survived plants | Other | Total |
|---|---|---|---|---|---|
| 1993 | 1,842 | 0 | 2,091 | 264 | 4,197 |
| | (0.439) | (0.000) | (0.498) | (0.063) | (1.00) |
| 1994 | 130 | 0 | 359 | 36 | 525 |
| | (0.248) | (0.000) | (0.684) | (0.069) | (1.00) |
| 1995 | 585 | 249 | 2,091 | 383 | 3,308 |
| | (0.177) | (0.075) | (0.632) | (0.116) | (1.00) |
| 1996 | 372 | 384 | 2,091 | 368 | 3,215 |
| | (0.116) | (0.119) | (0.650) | (0.114) | (1.00) |
| 1997 | 222 | 475 | 2,091 | 323 | 3,111 |
| | (0.071) | (0.153) | (0.672) | (0.104) | (1.00) |
| 1998 | 0 | 780 | 2,091 | 266 | 3,137 |
| | (0.000) | (0.249) | (0.667) | (0.085) | (1.00) |

Notes: Exit plants are plants that existed in 1993 but exited before 1998. New plants are plants that did not exist in 1993 but entered during 1995–1997 and continued to exist until 1998. Survived plants are plants that existed during 1993–1998, except 1994. The figures in parentheses indicate the fraction of each plant type in each year.

Table 1 shows that the sum of capital and the sum of value added reached over 90% of the pre-quake level in the three years after the quake, while the number of workers did not increase so rapidly and substantially. The number of workers remained at less than 80% of the pre-quake level in the three years after the quake[*4].

Table 2 reports number of plants by plant type in Kobe. I divided all plants into four types: exit, new, survived, and other. Exit plants are plants that existed in 1993 but exited before 1998. New plants are plants that did not exist in 1993 but entered during 1995–1997 and continued to exist until 1998. Survived plants are plants that existed during 1993–1998, except 1994. Any other plants that are excluded from the above three types are included in the "other" plant category. In this study, I focus only on survived plants since I analyze plant growth after the Kobe quake.

The terms "exit," "new," and "survived" do not indicate actual exit, entry, and survival for two reasons. First, the data does not cover plants with less than three employees. Second, the survey cannot follow a plant if the plant relocates across a city or town. Thus, exit plants include plants that relocated to another city or town from Kobe and new plants include

[*4] The number of workers in 1998 is even smaller than that in 1995. This tendency is similar to other variables, but the reason for the tendency is not clear.

Table 3: Number of survived plants and death toll in Kobe city (1995)

| District | No. of survived plants | Death toll |
|---|---|---|
| Higashi-Nada | 207 | 1,470 |
| Nada | 90 | 934 |
| Hyogo | 311 | 556 |
| Nagata | 565 | 921 |
| Suma | 119 | 399 |
| Tarumi* | 79 | 26 |
| Kita* | 79 | 13 |
| Chuo | 209 | 243 |
| Nishi* | 432 | 9 |
| | | |
| Most devastated area | 1,501 | 4,523 |
| Least devastated area | 590 | 48 |
| Total | 2,091 | 4,571 |

Notes: The least devastated districts are marked with *. The data on the number of survived plants is from the Census of Manufactures and that on the death toll is from Kobe city.

plants that relocated to Kobe from another city or town.

Table 2 shows that 1,842 plants, 43.9% of all plants in 1993, disappeared from the sample. This suggests that the impact of the quake on manufacturing plants in Kobe is rather substantial. The number of new plants, 780, is much less than the number of exit plants. Therefore, the total number of plants in Kobe decreased by over 25% (Table 1). Further, the number of survived plants is 2,091. The proportion of survived plants was approximately 50% before the quake, but reached 66.7% three years after the quake. Thus, it is evident that the relative importance of survived plants increased after the quake.

Table 3 reports the number of survived plants and death toll due to the quake in Kobe city by district. I classify nine districts into the most and least devastated areas and identify plants in the most devastated six districts as the affected plants; I do not use data on plants in the three least devastated districts: Tarumi, Kita, and Nishi. The number of plants in the most devastated and least devastated areas are 1,501 and 590, respectively. Further, the death toll in these two areas are 4,523 and 48, respectively.

# 5 Results

## 5.1 DID estimation

First, I discuss the OLS results from the DID estimation of equations (1) and (2). Table 4 reports the estimation results of equation (1) using log of capital as the dependent variable. The first column reports the estimation results using data for the years 1993 and 1995. The year 1993 is the base year for the analysis as it represents the pre-quake level of plants' variables. The second, third, and fourth columns report the results using data for the years 1996, 1997, and 1998, respectively, as well as the base year 1993.

The DID dummy, $kobe * after$, is insignificant in the two years after the quake and positively significant in 1998, three years after the quake. The estimated impact of the quake on plants' capital is approximately 6.3% $(= \exp(0.061))$. This implies that the capital of survived plants in the most devastated area of Kobe increased by 6.1%, on average. This result is in line with that of previous empirical studies such as Leiter et al. (2009) and the creative destruction hypothesis. Another dummy, $after$, is also positively significant, thereby suggesting that in both Kobe and other major cities in Japan, the capital of manufacturing plants increased by 1.7% $(= \exp(0.017))$, on average, three years after the quake. In the fourth column, the dummy, *kobe*, is negative and significant. Therefore, on average, plants in Kobe had a comparatively low level of capital, but succeeded in increasing their capital much more than plants in other major cities in Japan.

The results in Table 5 show that employment growth in manufacturing plants in the most devastated area of Kobe is significantly lower than other major cities in Japan. The DID coefficient, $kobe * after$, is significantly negative. The estimated impacts of the Kobe quake on employment three years after the quake is $-1.9\% (= 1 - \exp(-0.019))$. As the coefficient $after$ suggests, there was a decrease in the average number of workers in survived plants in major Japanese cities since 1995. Comparatively, there was a greater decrease in the number of workers in plants in Kobe than those in other major cities. In the same period, Kobe city experienced a large outflow of its population. Both facts suggest that the labor market shrunk after the Kobe quake. Thus, the negative employment effect of the Kobe quake is not consistent with the creative destruction hypothesis and the results of Leiter et al. (2009).

Finally, Table 6 reports the estimation results of equation (2). Again, negative effects of the quake are evident. The DID coefficients, $kobe * after$, are significantly negative, except the third column. The value added in

Table 4: Impact of the quake on capital growth: Kobe versus other major cities

| | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|
| Initial capital | 0.975*** | 0.971*** | 0.962*** | 0.954*** |
| | [0.002] | [0.002] | [0.003] | [0.003] |
| kobe | -0.026 | -0.043* | -0.049** | -0.048* |
| | [0.022] | [0.023] | [0.025] | [0.026] |
| after | 0.045*** | 0.031*** | 0.029*** | 0.017** |
| | [0.007] | [0.008] | [0.008] | [0.009] |
| kobe*after | -0.001 | -0.026 | 0.026 | 0.061** |
| | [0.025] | [0.026] | [0.028] | [0.029] |
| Observations | 20786 | 20661 | 20501 | 20235 |
| R-squared | 0.907 | 0.896 | 0.884 | 0.87 |

Notes: Standard errors are given in square brackets. Constants and industry fixed effects are suppressed. ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively. The base year is 1993.

Table 5: Impact of the quake on employment growth: Kobe versus other major cities

| | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|
| Initial employment | 0.987*** | 0.982*** | 0.978*** | 0.972*** |
| | [0.001] | [0.001] | [0.001] | [0.001] |
| kobe | -0.012** | -0.016*** | -0.015** | -0.010 |
| | [0.005] | [0.006] | [0.007] | [0.007] |
| after | -0.018*** | -0.025*** | -0.035*** | -0.071*** |
| | [0.002] | [0.002] | [0.002] | [0.002] |
| kobe*after | -0.017*** | -0.020*** | -0.019*** | -0.019** |
| | [0.006] | [0.006] | [0.007] | [0.008] |
| Observations | 47099 | 47092 | 46722 | 46721 |
| R-squared | 0.968 | 0.96 | 0.954 | 0.944 |

Notes: Standard errors are given in square brackets. Constants and industry fixed effects are suppressed. ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively. The base year is 1993.

Table 6: Impact of the quake on the growth of value added: Kobe versus other major cities

| | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|
| Initial capital | 0.190*** | 0.194*** | 0.196*** | 0.198*** |
| | [0.004] | [0.004] | [0.004] | [0.004] |
| Initial employment | 0.872*** | 0.862*** | 0.862*** | 0.858*** |
| | [0.007] | [0.007] | [0.007] | [0.007] |
| kobe | 0.093*** | 0.088*** | 0.088*** | 0.096*** |
| | [0.028] | [0.028] | [0.028] | [0.029] |
| after | 0.011 | 0.019** | 0.006 | -0.067*** |
| | [0.009] | [0.009] | [0.009] | [0.009] |
| kobe*after | -0.068** | -0.052* | -0.047 | -0.077** |
| | [0.030] | [0.030] | [0.031] | [0.032] |
| Observations | 23255 | 23254 | 23239 | 23234 |
| R-squared | 0.712 | 0.711 | 0.7 | 0.691 |

Notes: Standard errors are given in square brackets. Constants and industry fixed effects are suppressed. ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively. The base year is 1993.

survived plants in the most devastated area of Kobe decreased by approximately 7.4% ($= 1 - \exp(-0.077)$), which is more than that in other major cities, three years after the quake. This negative effect can be interpreted as the negative effect on productivity since I estimated the Cobb-Douglas type production function.

In summary, the significantly positive effects of the quake are found only for growth of capital. With regard to employment and value added, I found significantly negative effects of the quake. The positive effects on capital are consistent with the creative destruction hypothesis that natural disasters provide an impetus to capital stock. However, the negative effects on value added are not consistent with the hypothesis that natural disasters result in improvement in total productivity, given that the destroyed capital stock is replaced by new capital. Furthermore, the negative effects on employment are not in line with the conjecture in previous studies such as Skidmore and Toya (2002).

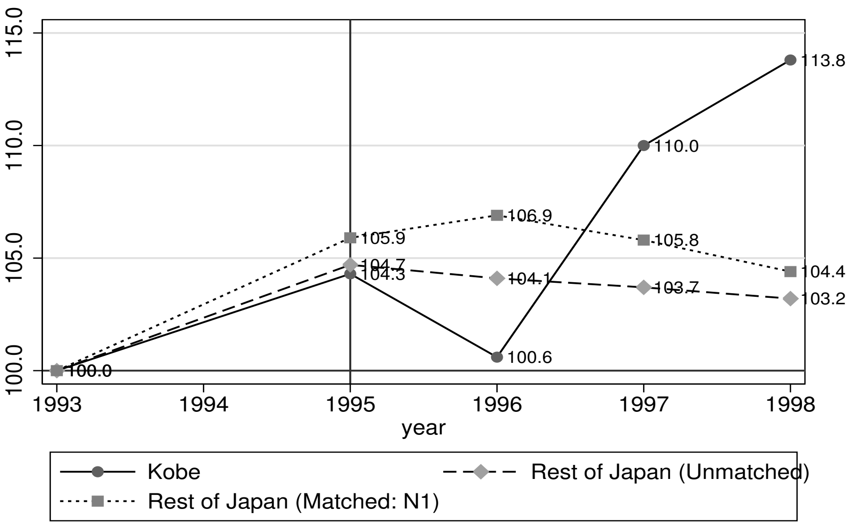


Figure 1: Impact of the quake on the log of capital

Notes: The dependent variable is the change from $t-2$ (1993) in the log of capital for the plants in Kobe and the matched and unmatched control groups in the rest of Japan. "Kobe" includes the most devastated districts of Kobe city only. The matched control group is selected by one-nearest-neighbor matching. The lines represent the average of each group.

## 5.2 Matching results

This section presents a comparison between affected plants in Kobe and unaffected plants in other areas of Japan, using the matching results. Unlike the DID estimation results, in this section, I select unaffected plants with similar pre-quake characteristics as the affected plants in Kobe. This enables us to estimate more rigorous impacts of the quake, controlling for pre-quake characteristics. The figures depict the main results and tables 8–10 in the Appendix present the detailed results.

Figure 1 compares the average capital growth between the survived plants in the most devastated area of Kobe and other areas. The solid line represents the survived plants in Kobe, while the broken line represents those in other areas. The short and long broken lines represent results using matched and unmatched unaffected plants, respectively. Figure 1 shows

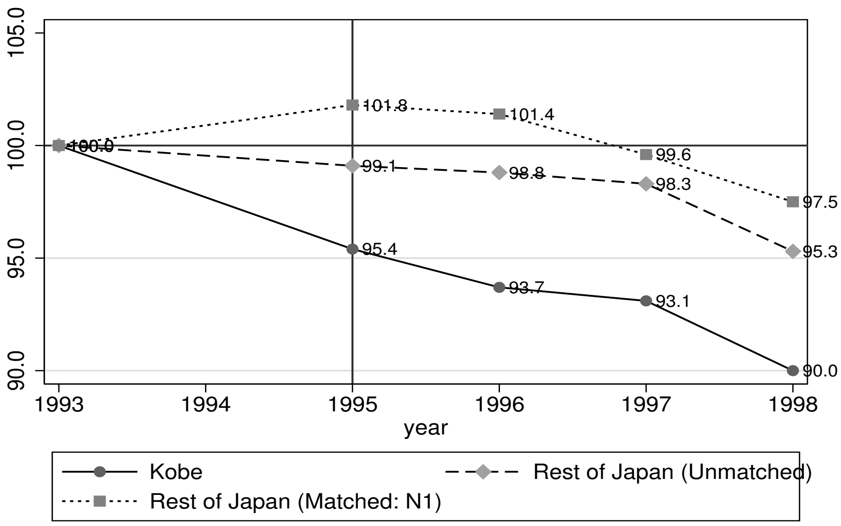


Figure 2: Impact of the quake on the log of employment

Notes: The dependent variable is the change from $t-2$ (1993) in the log of employment for the plants in Kobe and the matched and unmatched control groups in the rest of Japan. "Kobe" includes the most devastated districts of Kobe city only. The matched control group is selected by one-nearest-neighbor matching. The lines represent the average of each group.

that there is a sharp difference in the average capital growth path between affected and unaffected plants.

After a decrease in the capital of plants in Kobe in 1996, there was an increase in their capital by 13.8% until 1998. There was an increase in the capital of matched plants in other major cities of Japan by 4.4%, while that in unmatched plants increased by 3.2%. Therefore, the average impact of the quake, ATT, three years after the quake is 9.4%, as reported in Table 8 of the Appendix[*5]. The results confirm the positive effects of the quake on capital, as in previous sections, and are in line with the creative destruction hypothesis.

[*5] It is difficult to directly compare the magnitude of the impacts of the quake between this and previous sections, since this section employs a different specification and sample; however, we can compare the sign of the impacts.

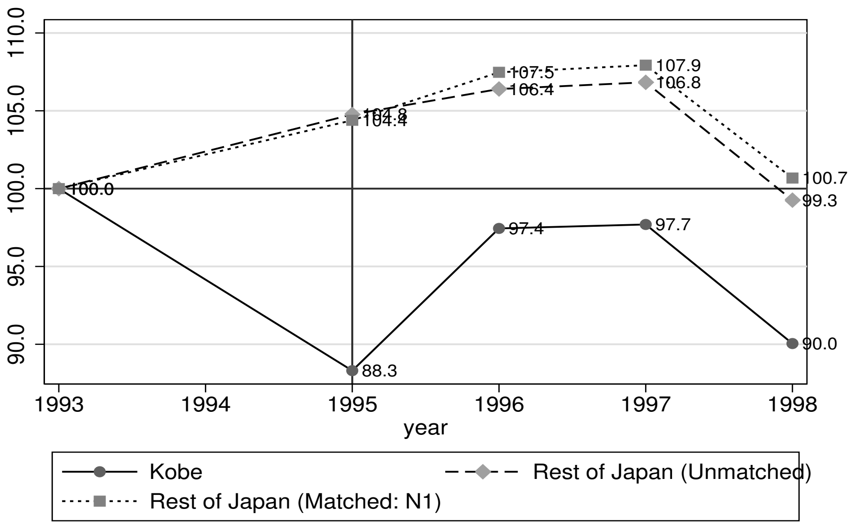


Figure 3: Impact of the quake on the log of value added

Notes: The dependent variable is the change from $t-2$ (1993) in the log of value added for the plants in Kobe and the matched and unmatched control groups in the rest of Japan. "Kobe" includes the most devastated districts of Kobe city only. The matched control group is selected by one-nearest-neighbor matching. The lines represent the average of each group.

Next, Figure 2 displays the average growth path of employment by each group. There was a much larger decrease in the number of workers in plants in Kobe in the three years after the quake than that in matched and unmatched control groups in other areas of Japan. In the three years after the quake, the number of workers decreased by 10.0%. This negative employment impact of the quake is the same as that found in the previous section. The average employment impact of the quake is -7.4%.

Finally, Figure 3 shows the impacts of the quake on the log of value added. Unlike plants in other areas of Japan, plants in Kobe have largely reduced value added by 10.0% until the end of 1998. The estimated impact of the quake on value added is -10.6%. The result is, again, not consistent with the creative destruction hypothesis.

In sum, the results of the matching method discussed in this section suggest that there was an increase in the capital in plants in Kobe after the quake, but no increase in value added. In addition, there was also a decrease in the number of workers. The empirical results suggest that the large increase in capital and decrease in labor resulted in a less productive factor composition.

## 6 Conclusion

This study investigated the effects of the Kobe quake in 1995 on the growth of capital, employment, and value added in affected plants. I employed plant-level data and both simple DID estimation and matching approaches to obtain the pure effects of the quake. Using plant-level data, this study provides the first evidence that the impact of the Kobe quake on employment and value added are significantly negative, while the impact on capital is positive. The results are not consistent with the creative destruction or creative disaster hypothesis that natural disasters enhance plants' productivity by encouraging plants to replace their existing capital with new capital and adopt new technology. Rather, the results suggest that there was over-investment in physical capital in affected plants in Kobe and a failure to enhance productivity.

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## Appendix 1: Descriptive statistics

Table 7: Aggregated variables of manufacturing plants in Kobe city by plant type (1993–2000)

| Value added (billion) | Exit plant | New plant | Survived plant | Other | Total |
|---|---|---|---|---|---|
| 1993 | 219.7 | 0.0 | 644.0 | 27.4 | 891.1 |
| | (0.247) | (0.000) | (0.723) | (0.031) | |
| 1994 | 69.9 | 0.0 | 310.3 | 16.2 | 396.3 |
| | (0.176) | (0.000) | (0.783) | (0.041) | |
| 1995 | 86.6 | 16.0 | 623.8 | 61.1 | 787.4 |
| | (0.110) | (0.020) | (0.792) | (0.078) | |
| 1996 | 59.4 | 44.2 | 690.5 | 43.7 | 837.8 |
| | (0.071) | (0.053) | (0.824) | (0.052) | |
| 1997 | 33.3 | 83.4 | 644.5 | 48.2 | 809.4 |
| | (0.041) | (0.103) | (0.796) | (0.060) | |
| 1998 | 0.0 | 112.7 | 640.8 | 46.2 | 799.7 |
| | (0.000) | (0.141) | (0.801) | (0.058) | |

| No. of workers | Exit plants | New plants | Survived plants | Other | Total |
|---|---|---|---|---|---|
| 1993 | 26,941 | 0 | 75,170 | 3,116 | 105,227 |
| | (0.256) | (0.000) | (0.714) | (0.030) | |
| 1994 | 4,261 | 0 | 37,189 | 424 | 41,874 |
| | (0.102) | (0.000) | (0.888) | (0.010) | |
| 1995 | 10,854 | 2,763 | 70,327 | 4,263 | 88,207 |
| | (0.123) | (0.031) | (0.797) | (0.048) | |
| 1996 | 6,048 | 4,522 | 69,197 | 3,507 | 83,274 |
| | (0.073) | (0.054) | (0.831) | (0.042) | |
| 1997 | 3,520 | 5,775 | 68,816 | 3,751 | 81,862 |
| | (0.043) | (0.071) | (0.841) | (0.046) | |
| 1998 | 0 | 10,186 | 66,692 | 3,578 | 80,456 |
| | (0.000) | (0.127) | (0.829) | (0.044) | |

| Capital (billion) | Exit plants | New plants | Survived plants | Other | Total |
|---|---|---|---|---|---|
| 1993 | 65.7 | 0.0 | 337.6 | 9.8 | 413.1 |
| | (0.159) | (0.000) | (0.817) | (0.024) | |
| 1994 | 9.4 | 0.0 | 169.1 | 0.4 | 178.9 |
| | (0.053) | (0.000) | (0.945) | (0.002) | |
| 1995 | 32.0 | 2.3 | 330.7 | 18.3 | 383.3 |
| | (0.083) | (0.006) | (0.863) | (0.048) | |
| 1996 | 18.7 | 6.9 | 316.3 | 13.8 | 355.7 |
| | (0.053) | (0.019) | (0.889) | (0.039) | |
| 1997 | 12.9 | 12.9 | 317.0 | 14.4 | 357.2 |
| | (0.036) | (0.036) | (0.888) | (0.040) | |
| 1998 | 0.0 | 39.7 | 297.0 | 17.9 | 354.7 |
| | (0.000) | (0.112) | (0.837) | (0.051) | |

Notes: Exit plants are plants that existed in 1993, but exited before 1998. New plants are plants that did not exist in 1993, but entered during the period 1995–1997 and continued to exist until 1998. Survived plants are plants that existed during the period 1993–1998, except 1994. The figures in parentheses indicate the share of each plant type in each year.

## Appendix 2: Matching results

Table 8: The impact of the quake on the capital of survived manufacturing firms in the most devastated area of Kobe

| Outcome: ln K | No. of treated firms | | (1) Treated | (2) Control | (3) ATT | (4) t-value | | (5) Balancing property |
|---|---|---|---|---|---|---|---|---|
| One-nearest-neighbor matching | 366 | t | 0.043 | 0.059 | -0.016 | -0.36 | | Yes |
| | | t + 1 | 0.006 | 0.069 | -0.062 | -1.23 | | Yes |
| | | t + 2 | 0.100 | 0.058 | 0.042 | 0.76 | | Yes |
| | | t + 3 | 0.138 | 0.044 | 0.094 | 1.57 | | Yes |
| Three-nearest-neighbor matching | 366 | t | 0.043 | 0.030 | 0.013 | 0.36 | | Yes |
| | | t + 1 | 0.006 | 0.034 | -0.028 | -0.69 | | Yes |
| | | t + 2 | 0.100 | 0.012 | 0.088 | 1.92 | * | Yes |
| | | t + 3 | 0.138 | -0.009 | 0.147 | 3.00 | ** | Yes |
| Unmatched results | 366 | t | 0.043 | 0.047 | -0.004 | -0.12 | | |
| | | t + 1 | 0.006 | 0.041 | -0.035 | -1.01 | | |
| | | t + 2 | 0.100 | 0.037 | 0.063 | 1.67 | * | |
| | | t + 3 | 0.138 | 0.032 | 0.106 | 2.61 | ** | |

Notes: The figures in columns (1) and (2) are the change from $t - 2$ (1993) in the log of variables. The common support condition is imposed. ATT is the average treatment effect on treated plants. ** and * indicate significance at the 5% and 10% levels, respectively.

Table 9: The impact of the quake on number of workers in survived manufacturing firms in the most devastated area of Kobe

| Outcome: ln Employment | No. of treated firms | | (1) Treated | (2) Control | (3) ATT | (4) t-value | | (5) Balancing property |
|---|---|---|---|---|---|---|---|---|
| One-nearest-neighbor matching | 1,234 | t | -0.046 | 0.018 | -0.065 | -2.64 | ** | Yes |
| | | t + 1 | -0.063 | 0.014 | -0.077 | -2.83 | ** | Yes |
| | | t + 2 | -0.069 | -0.004 | -0.065 | -2.01 | ** | Yes |
| | | t + 3 | -0.100 | -0.025 | -0.074 | -2.18 | ** | Yes |
| Three-nearest-neighbor matching | 1,234 | t | -0.046 | 0.022 | -0.068 | -4.31 | ** | Yes |
| | | t + 1 | -0.063 | 0.023 | -0.086 | -4.61 | ** | Yes |
| | | t + 2 | -0.069 | 0.013 | -0.082 | -3.74 | ** | Yes |
| | | t + 3 | -0.100 | -0.013 | -0.087 | -3.72 | ** | Yes |
| Unmatched results | 1,234 | t | -0.046 | -0.009 | -0.037 | -6.15 | ** | |
| | | t + 1 | -0.063 | -0.012 | -0.051 | -7.21 | ** | |
| | | t + 2 | -0.069 | -0.017 | -0.052 | -6.51 | ** | |
| | | t + 3 | -0.100 | -0.047 | -0.052 | -5.94 | ** | |

Notes: The figures in columns (1) and (2) are the change from $t-2$ (1993) in the log of variables. The common support condition is imposed. ATT is the average treatment effect on treated plants. ** and * indicate significance at the 5% and 10% levels, respectively.

Table 10: The impact of the quake on value added of survived manufacturing firms in the most devastated area of Kobe

| Outcome: ln Value added | No. of treated firms | | (1) Treated | (2) Control | (3) ATT | (4) t-value | | (5) Balancing property |
|---|---|---|---|---|---|---|---|---|
| One-nearest-neighbor matching | 1,148 | t | -0.117 | 0.044 | -0.161 | -6.62 | ** | Yes |
| | | t + 1 | -0.026 | 0.075 | -0.100 | -3.97 | ** | Yes |
| | | t + 2 | -0.023 | 0.079 | -0.102 | -4.12 | ** | Yes |
| | | t + 3 | -0.100 | 0.007 | -0.106 | -4.02 | ** | Yes |
| Three-nearest-neighbor matching | 1,148 | t | -0.117 | 0.047 | -0.164 | -7.81 | ** | Yes |
| | | t + 1 | -0.026 | 0.067 | -0.093 | -4.43 | ** | Yes |
| | | t + 2 | -0.023 | 0.071 | -0.095 | -4.63 | ** | Yes |
| | | t + 3 | -0.100 | -0.013 | -0.086 | -3.93 | ** | Yes |
| Unmatched results | 1,148 | t | -0.117 | 0.048 | -0.165 | -11.17 | ** | |
| | | t + 1 | -0.026 | 0.064 | -0.090 | -5.66 | ** | |
| | | t + 2 | -0.023 | 0.068 | -0.091 | -5.37 | ** | |
| | | t + 3 | -0.100 | -0.007 | -0.092 | -5.05 | ** | |

Notes: The figures in columns (1) and (2) are the change from $t - 2$ (1993) in the log of variables. The common support condition is imposed. ATT is the average treatment effect on treated plants. ** and * indicate significance at the 5% and 10% levels, respectively.